EVALUATION OF WHEAT VARIETY, STOCKING DENSITY AND SELF-LIMITED ENERGY SUPPLEMENTS ON PERFORMANCE OF STEERS GRAZING WINTER WHEAT

By

STEVEN IRA PAISLEY

Bachelor of Science
University of Wyoming
Laramie, Wyoming
1993

Master of Science
University of Wyoming
Laramie, Wyoming
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Thesis Approved:

Gerald W. Horn
Thesis Advisor

David Lalman

Larry A. Redmon

F. N. Owens

D. S. Buchanan

Wayne B. Powell
Dean of the Graduate College

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INTRODUCTION

Beef cattle production is an important economic enterprise in the state of Oklahoma, generating approximately $1 billion in revenue in 1996, by far the most important agricultural product in the state (OASS, 1997). Winter wheat production also is important, ranked third in the state with an estimated $461 million in annual sales (OASS, 1997). Because of the large livestock and wheat base, grazing winter wheat is a popular economic enterprise for wheat producers in Oklahoma, with the OASS estimating that 1.6 million ha (57% of the total hectares planted to winter wheat) are grazed (Epplin, 1997). Of the 1.6 million ha of wheat that are grazed, .91 million ha, or 56.8% of those grazed hectares (32.4% of total planted acres) also produce a grain crop. Determining the factors that affect forage and grain yield in these dual-purpose systems, and developing supplementation programs that produce consistent improvements in animal performance will help to increase net returns from grazing and grain operations in the Southern Great Plains.

Winter wheat variety can potentially affect gain/steer, gain/ha and grain yield/ha in grazing and grain operations. Buckner and Raymer (1990) reported that soft red winter wheat cultivars differed in early season forage production. Additionally, Krenzer et al. (1996), measuring both forage production and grain yield of 12 wheat varieties, reported a $81.27 range in calculated net return/ha across the 12 varieties based on grain yield and clipping data.

One objective of the Expanded Wheat Pasture Research Program at Oklahoma State University has been to develop supplementation programs that will decrease production risks associated with growing cattle grazing winter wheat pasture. One strategy has been to develop a self-limited energy supplement containing monensin. Horn et al. (1990, 1992) and Beck et al. (1993) reported that providing this self-limited supplement to growing steers grazing winter wheat increased daily gains by .20 to .24 kg/d over cattle receiving a mineral supplement alone (Horn et al., 1990, 1992; Beck et al., 1993). Daily supplement intake ranged from .91 to 1.36 kg/day; this resulted in a supplement conversion ratio of 5.5 to 6.5 kg of supplement/kg of increased gain. Horn et al. (1992, 1997) estimated that the increased gain alone increased return/steer by $14 to $30 depending on the cost of feed.

Tweeten (1982) estimated that approximately 1.5 million stocker cattle graze wheat pasture in Oklahoma during years of favorable wheat growth. When estimates of the potential benefits of supplementation are multiplied by the number of growing cattle grazing wheat in Oklahoma, it emphasizes the importance of wheat pasture supplements and how they can improve animal performance and net returns to grazing and grain operations.

The objective of our research was to improve the efficiency of wheat pasture grazing and grain operations in the Southern Great Plains through further development of a self-limited monensin-containing energy supplement for growing steers grazing winter wheat. Additional research evaluated the effect of wheat variety on beef production and grain yield in wheat pasture grazing and grain operations.

CHAPTER II

REVIEW OF LITERATURE

Effects of Grazing Winter Wheat on Forage and Grain Production

Tweeten (1982) estimated that 1.5 million stocker cattle graze winter wheat pasture in Oklahoma alone. While improving net return per hectare, grazing wheat during the vegetative stage potentially can reduce wheat forage production and plant survival rate depending on grazing severity and weather conditions., ultimately affecting overall carrying capacity. In addition to affecting forage production and overall carrying capacity, grazing also can affect subsequent grain yield. Therefore, it is important to determine how management factors such as intensity and timing of grazing, grazing termination date and wheat variety affect forage and grain production and net returns per hectare.

Forage Production

Intensity and length of grazing can affect forage production. Having adequate leaf surface area remaining after defoliation (grazing) is important for forage regrowth potential throughout the growing season. Milthorpe and Davidson (1966), Smith (1974), and Booysen and Nelson (1975) all reported that severe defoliation reduced regrowth of ryegrass, timothy and orchardgrass, respectively. In addition, continued severe grazing can deplete the plant's carbohydrate reserves, further reducing regrowth potential (Ward and Blaser, 1961; Smith 1974). Reduced forage regrowth then leads to a reduction in overall carrying capacity. Severely grazing winter wheat can also increase plant tiller mortality (Christiansen et al., 1989; Winter and Thompson, 1987, 1990). These decreases in wheat densities, or plant survival rate, during the cold winter months have been attributed to decreased carbohydrate reserves in the plant as well as reduced soil coverage, reducing the plant protection during hard winter freezes.

Grain Production

Attempts to determine the effect of grazing on and grain production in winter wheat have produced a variety of responses. Grazing can be beneficial, increasing grain yield by reducing the incidence of lodging when ideal growing conditions during the fall and winter months result in increased forage growth, as reported by Sprague (1954), Aldrich (1959) and Christiansen et al. (1989). Several research trials detected that grazing had no effect on wheat yield as long as grazing was terminated prior to jointing (Shipley and Regier 1972; Cole et al., 1977; Petr and Daughtrey, 1978). However, additional trials reported decreased grain yields when winter wheat was grazed (Hubbard and Harper, 1949; Morris and Gardner, 1958; Schlehuber et al., 1954), supposedly due to the removal of the terminal meristem by the grazing animals. Terminal meristems are responsible for formation of the seed head, and removal of terminal meristems by late-season grazing reduces the number of seed heads formed, and lowers grain yields. Additional factors that can influence the grain yield response to grazing include available moisture (i.e., dryland vs. irrigated) and(or) length and severity of the winter. More importantly, recent research, as reviewed by Redmon et al. (1995), indicates that subsequent grain yield responses to grazing can depend upon variety or type, especially mature plant height (tall vs semidwarf varieties). While forage and grain production depend upon seasonal weather and precipitation, grazing management and wheat variety selection represent two factors under direct control by the producer that ultimately influence net returns/hectare. Further research in determining the correct stocking density, optimal cattle removal date, and ideal wheat variety or type for grazing and grain operations is important for producers interested in maximizing net returns.

Severity of Grazing and Grazing Termination Date. Length and(or) timing of grazing winter wheat may affect subsequent grain yield. Petr and Daughtrey (1978) suggested that moderate grazing did not reduce grain yield when stocking rate was light enough to avoid continuous, complete removal of top growth. Christiansen et al. (1989) monitored the effects of grazing dryland wheat (Triticum aestivum var. TAM W-101) over a three year period, evaluating fall, spring, and fall plus spring grazing on grain production. During each grazing period, wheat was grazed at two intensities. Stocking density (steers/acre) was the same for both grazing treatments; intensity was altered by adjusting grazing duration. Heavy fall stocking rates were followed by an extremely cold winter during year one. Fall-only grazing decreased grain yield as compared with ungrazed plots, with an additional grain yield reduction within the two grazing intensities. Decreased grain yields were attributed to trampling and plant mortality, perhaps amplified by the cold temperatures. Final plant densities, measured as the length of uninterrupted wheat stands along four drill-row subsamples, were 79, 56, and 40% wheat for ungrazed, light, and heavy grazed treatments indicating that even ungrazed wheat was affected by the severe winter weather. In year two, grazing was limited to a short spring period. The short spring grazing season had no effect on grain yield, and wheat densities were not significantly altered by grazing. Weather in year three allowed fall and(or) spring grazing. Light fall-only grazing increased grain yield over ungrazed plots due to a reduction in lodging, while light spring grazing decreased grain yield by about 30%. Both grazing intensities for combination fall and spring grazing reduced grain yields to a degree similar to light spring grazing. Although grazing effects on grain yield varied depending on grazing treatment, variability in these results illustrate the importance of time of grazing and(or) grazing severity on subsequent grain yield. During year one, heavy stocking rates reduced grain yields, whereas in year two, light grazing (because of low forage production) had no effect on subsequent grain yields. Results from year three indicated that spring grazing was more detrimental to grain production than fall grazing. Winter et al. (1990) evaluated three mature heights of wheat with two termination dates. While grazing termination date affected grain yield (discussed later), yields were reduced more by severe late grazing than by moderate late grazing. Although Christiansen et al. (1989) may have produced more trampling losses due to their use of very heavy stocking densities and short duration grazing, research by Petr and Daughtrey (1978) and Winter (1990) still suggested that grazing severity, regardless of pull-off date, can affect subsequent grain yield by reducing plant survival rates; additionally, the effects grazing can be amplified by severity of the winter.

Grazing wheat too late into the Winter, or early Spring, also can reduce grain yield. Several researchers have reported that grain yield was decreased when the terminal meristem was removed by grazing animals (Hubbard and Harper, 1949; Morris and Gardner, 1958; Schlehuber et al., 1954). Removal of the growing point, or terminal meristem, may not be the only concern when grazing semi-dwarf wheat varieties during and after early jointing. Subsequent grain yield also may depend on the plants ability to produce and to fill a seed head following grazing. Dunphy et al. (1982) terminated clipping at early, mid- and late joint stages without removing the terminal meristem. Grain yield reductions associated with forage removal time ranged from 4% for early joint to 84% for to late joint stage as compared to yield of unclipped wheat. In a companion paper (Dunphy et al., 1984), LAI (leaf area index) at late jointing was significantly correlated with subsequent grain yield. Winter and Thompson (1987) terminated grazing at five dates ranging from February 1 to April 13, and determined that grazing beyond March 6 resulted in reduced grain yields. Finally, Redmon et al. (1996) evaluated timing of grazing termination on subsequent grain yield. Grain yield was decreased by 83 kg/ha for each day that grazing was extended beyond the presence of first hollow stem. Early removal of livestock in wheat pasture may be important for grain yield not only to prevent removal of the terminal meristem, but also to allow sufficient time for plants to achieve maximum grain production.

Effect of variety. Grain yield responses to grazing also may depend on the variety of wheat being grazed. Shipley and Regier (1972) grazed irrigated plots planted to Tascosa, a tall variety, for different durations, removing cattle on March 1, March 20, March 30, April 10, and April 20. Three-year average wheat yields were 2.57, 2.88, 2.63, 2.67, 1.93, and 1.27 Mg ha^{-1}, respectively for ungrazed wheat and the five pull-off dates. Grain yield was not significantly reduced unless cattle were removed on or after April 10. In contrast, Winter and Thompson (1987) reported that grain yields by a semidwarf wheat variety were significantly decreased when grazing was extended past March 6. Differences in grazing effects between the two trials may be related to variety type (tall vs. semidwarf), and(or) overall yield differences (2.33 vs. 3.86 Mg/ha). The earlier critical grazing termination date reported by Winter and Thompson (1987) suggest that semidwarf varieties are more sensitive to grazing than tall varieties. In an attempt to characterize wheat height by production system interactions, Winter et al. (1990) evaluated tall, intermediate, and short varieties in grain-only and grazing plus grain systems. Although short and semidwarf varieties produced more grain than the tall variety in the grain-only system, grain yields of these varieties were reduced by grazing; whereas grazing had little effect on grain yield of the tall variety. Differences in grazing response resulted in similar grain yields for all heights of wheat in the grazing plus grain system. Winter and Musick (1991) reported similar results in a later trial evaluating the variety x system interaction using 11 wheat varieties. Small and semidwarf varieties consistently produced more grain in grain-only systems, while grain yields were similar for all heights in the grazing and grain system. They concluded that grazing effects in productive environments may depend on plant height and(or) yield potential of the variety, because grazing tended to have a greater effect on the most productive varieties.

Stocking Rate Models

In addition to forage production and grain yield, cattle performance also is very important for wheat pasture grazing and grain operations. Perhaps the most important factor affecting individual animal performance is the number of cattle/hectare. Stocking rate models were first developed as an aid in interpreting and comparing multiple grazing studies across various stocking rates and forage types. Initially designed to evaluate animal performance by characterizing the relationship between animal performance and available forage, researchers eventually realized that these modeling techniques also could be used to determine economic optimum stocking rates. Ultimately the main goal of forage-based production systems is to “graze the forage produced in such a way as to obtain the greatest yield of animals and animal products at the lowest possible cost of production" (Osborne and Reid, 1952) while maintaining long-term forage composition and quality. Generally net return is maximized somewhere between maximum gains/animal and maximum gains/hectare (Hart et al. 1991).

One of the first steps for determining the optimum stocking rate is to develop a stocking rate model that accurately estimates animal production at various stocking rates. Although researchers have attempted to relate animal performance to stocking rates, there is little agreement about the exact nature of the relationship between individual animal gain and stocking rate. This relationship is further complicated by the various ways of describing stocking rate. Stocking rates are expressed as either animals/unit area or area/animal. Stocking rate also can be described through estimating the available forage per animal or per unit area. Schultz (1959), who calculated gain per acre, and Austenson et al. (1959) who measured milk production per acre both related animal production to forage production/acre and available forage/animal. Finally, Mott (1960) and Jones and Sandland, (1974) attempted to predict animal performance across a wide variety of forages and environments by expressing animal performance as a ratio of observed:optimum performance, a procedure that assigned "optimum" performance values, or estimates of maximum gains/animal for each forage and(or) environment. "Optimum" values were an attempt to factor in the "gain potential" of grazed forages based on forage quality and availability.

In general, as stocking rate is increased, individual animal performance decreases. However, many researchers believe that there is a critical stocking rate, or a point where animal performance is maximized, and that further reductions in stocking rate do not affect animal performance. Both the existence of a critical stocking rate, as well as the shape of the animal response curve at rates greater than critical are still disputed.

Critical Stocking Rate

Even though initial stocking rate models did not include a critical stocking rate, important relationships between stocking rate and animal performance were recognized. Harlan (1958) was one of the first researchers to relate animal performance and stocking rate for a wide variety of forage types and climates ranging from Sonora, Texas to Mandan, North Dakota. He determined that the relationship between gain per animal and stocking rate (acres/steer) was a double exponential of the form $y = 16 - 2^{2^{x}/4}$, where y is individual animal performance and x is stocking rate (acres/steer). His model suggested that the relationship between animal performance and stocking rate was curvilinear. Although his model did not include a critical stocking rate, suggesting that animal performance was never maximized even with the lightest stocking densities, it indicated that animal performance plateaued at the lightest stocking rates, and animal gains dropped dramatically as stocking rate increased from heavy to very heavy. Riewe (1961) reviewed many of the same trials as Harlan (1958); however, he chose to express stocking rate as animal/unit area, the inverse of the expression used by Harlan. Riewe calculated that animal performance increased linearly as stocking rate decreased until maximum gain potential of the animals is reached. At stocking rates less than critical, animal weight gains were independent of stocking rate, a relationship recognized previously by Blaser et al. (1956). Riewe (1961) also found that the lightest stocking rates did not always produce the highest gains per animal. Animal gains may be reduced partially due to a decreased quality of the available forage, as ungrazed forage can mature and become rank, decreasing in quality to the point were animal performance may be reduced despite unlimited availability. While Jones and Sandland (1974) found no evidence of a plateau, or critical stocking rate, Petersen et al. (1965), Owen and Ridgman (1968), Conniffe et al. (1970), Conway (1974) and Hart (1978) all supported the theory of a critical stocking rate. While several researchers agree on the existence of a critical stocking rate, disagreement continues concerning the relationship of the animal response curve at stocking rates greater than the critical stocking rate.

Non-Linear Models

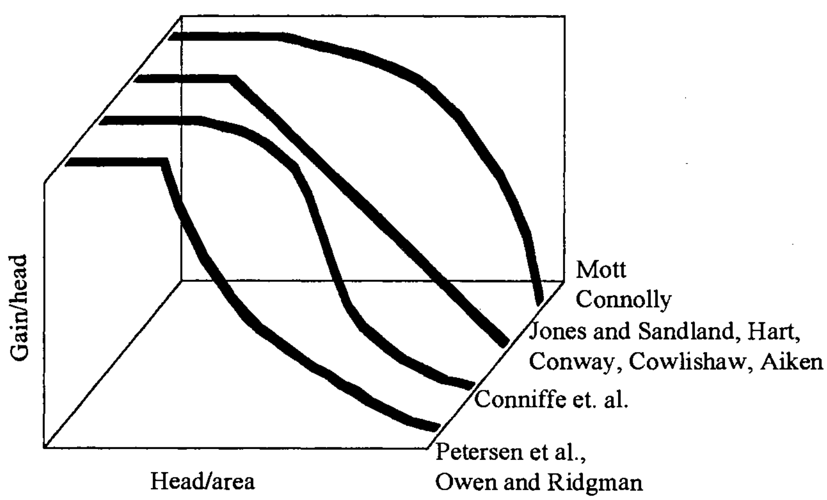
Several grazing models suggest that animal responses to stocking rates greater than the critical rate are curvilinear, although there is little similarity in the shape of the suggested curves (Figure 1). Mott (1960) used ratios of actual/optimum values similar to Jones and Sandland (1974) to estimate animal performance based on stocking rate; however, optimum values are based on measurements determined at optimum grazing pressure (lb forage/steer) rather than steers/acre as used by Jones and Sandland (1974). Mott (1960) converted gain/animal, gain/acre and stocking rate measurements into a ratio of observed values/values achieved at an optimum grazing pressure, resulting in a curvilinear relationship of $y = k\text{-}ab^x$, where y = product produced ÷ product produced at optimum stocking rate and x = a ratio of actual stocking rate ÷ stocking rate at the optimum grazing pressure. Despite calculating these ratios based on optimum grazing pressures, the criteria for determining optimum stocking rates, or grazing pressures, was never defined. In an attempt to isolate and characterize the animal response as forage availability decreases, Petersen et al. (1965) developed a theoretical framework using 80 albino rats and one diet fed at seven levels to represent decreased intakes associated with increased stocking rates. Basing their experimental design on several assumptions concerning animal intake and behavior as well as forage quality, the model of Petersen et al. (1965) reported that when diets are fed in excess of consumption, animal response is independent of feeding level. Once the critical intake level is reached, animal performance decreases dramatically at first, eventually leveling off, which generates a concave response curve as feeding level is reduced. These results conflict with those of Mott (1960), who described a convex response curve as stocking rate increased. Petersen's model described an instantaneous situation, which may or may not be accurate in a long term grazing trial because of possible changes in diet selection and(or) seasonal changes in forage quality and availability associated with season-long trials. Denny and Barnes (1977) and Gammon and Roberts (1978) reported that forced grazing associated with heavily stocked pastures affected nutrient intake of steers by reducing forage intake and(or) diet selection. The model suggested by Owen and Ridgman (1968) agrees with that of Petersen et al. (1965), however, animal performance is again based on short grazing periods assuming constant forage quality. Longer time periods may change the shape of these curves.

Linear Models

Riewe, (1961,1963), Cowlishaw (1969), Conway (1974), Jones and Sandland, (1974) Hart (1972, 1978) and Bransby (1982, 1988) all supported the linear model used by Riewe (1961); however, the slope of the response varied with the quality of the grazed forage as well as the length of the grazing period. Cowlishaw (1969) plotted the relationship of animal performance vs stocking rate (animals/acre) across several forage types and grazing period lengths. He determined that longer grazing periods and lower quality forages were associated with steeper slopes, while short duration grazing in conjunction with high quality forages produced a relatively flat curve. Jones and Sandland (1974) and Sandland and Jones (1975) also suggested a linear relationship; however, they converted both animal performance and stocking rates into ratios of actual values/optimum values. The use of the stocking rate ratio as opposed to raw stocking rates appears to adjust stocking rates for potential differences in forage production between highly productive pastures and sparsely vegetated rangeland, with the "optimum" value being an estimation of the gain potential of the forage. While converting stocking rates and performance data into ratios may improve the accuracy of predicting animal performance across several environments, the criteria for determining the "optimum" stocking rate is never defined. The optimum stocking rate may actually be unique to each situation and(or) researcher, dependent upon level of management, animal type, production goals, and long-term expectations for pasture condition and productivity. Additionally, attempts to characterize gain responses over a wide range of forages may jeopardize the model's ability to predict animal performance within each specific production system.

Diverse opinions exist on how to best describe animal gain/area as stocking rate increases. Models designed to estimate individual animal performance for a specific production system lose their accuracy when applied to numerous grazing trials and diverse forage quantities and qualities. As suggested by Hart (1978), the concave relationship describing the animal response as forage availability decreases proposed by Peterson et al. (1965) may accurately describe the animal/forage relationship at a specific time during the grazing period, but changes in the quantity and quality of forage, as evaluated by Noy-Meir (1978), alter this relationship. Changes in forage production, forage quality and animal requirements throughout the grazing season can change the shape of the animal response curve throughout the grazing season. Additionally, forage quality and length of grazing season may have an effect on the slope and(or) curve of the line describing animal performance at various stocking rates, as suggested by Cowlishaw (1969). While the relationships between animal performance and stocking rate may not be linear over the full range in grazing intensities, Bransby et al. (1988) found that linear functions provided good approximations across a limited range of grazing intensities. Such linear equations should sufficiency characterize most grazing responses across most of the ranges in stocking rate encountered.

Figure 1. Proposed relationships between stocking rate and weight gain per animal as described by Hart (1978).



Gain/animal vs Gain/acre

Profitable pasture management requires that the cattleman knows the rate at which beef gains increase or decrease in response to a change in forage yield or stocking rate (Hart, 1972). He also must know the costs of making such changes, and the price he is likely to be paid for the beef produced. Stocking rate has an over-riding impact on profitability of grazing systems. Choosing the proper stocking rate allows the producer to compromise between under-grazing early in the season, which allows forage to lose quality before it consumed, and over-grazing late in the season, when quantity as well as quality limits animal performance (Hart, 1991). Aiken et al. (1991) observed that at light stocking rates, forage on offer is high, allowing for a high degree of selectivity; this results in maximum gain per animal but reduced gain per hectare. Higher stocking rates decrease individual animal gains by reducing the degree of grazing selectivity, but increase gain per hectare until maximum gain per hectare is obtained. Increasing the stocking rates beyond that point will result in decreases in both gain per animal and gain per hectare, assuming that total dry matter availability is not limiting. Riewe (1961) reported that the heaviest stocking rate did not always produce the greatest gains per acre. His conclusions agreed with those of Harlan (1958), suggesting that gain/acre continues to increase despite decreases in gain/animal until heavy stocking rates decrease animal performance so dramatically that animal production per acre is reduced. Additionally, Riewe (1961) and Jones and Sandland (1974) theorized that the stocking rate at the point of no gain is approximately twice the number of animals required to produce the maximuim gain per acre. Restated, maximum gain per acre is achieved at a stocking rate ½ that where animal gain is zero. Mott (1960) suggested that maximum gain/acre occurs at a slightly heavier stocking rate than maximum gain per animal. The optimum stocking rate is described as the stocking rate where the lines describing total weight gain/animal and gain/acre intersect. McMeekan and Walshe (1963) evaluated the effects of grazing management and stocking rate on overall production within New Zealand dairy operations. Two extremes of grazing management (rotational vs continuous) were compared at two stocking rates over four complete production years. Each treatment involved a self-contained dairy farm unit composed of 40 to 42 cows. While animal performance was measured in milk production, they also found that maximum production per acre occured beyond the point that individual animal performance had been maximized, and that stocking rate was the dominant factor in determining the efficiency of pasture utilization and profitability. Finally, Hart (1978, 1991) made the distinction between maximum gain/animal, maximum gain/acre and maximum net returns/acre; he used these functions to determine the stocking rate where maximum net returns/acre was achieved. The most profitable stocking rates always occurred between the stocking rate producing the maximum gain per animal and the stocking rate producing maximum gain/acre. The exact rate is determined by product prices (beef, milk, weaning weight, etc.) and carrying costs.

Repeated Observations vs Covariance Models.

The inclusion of three or more stocking rates per pasture treatments appears to be a necessary feature of grazing trials because: 1) No single stocking rate is optimum for a given pasture under all economic situations, and 2) a stocking rate x treatment interaction may exist, and for comparing differences between treatments, this could well be the most important finding obtained in a grazing trial. While Brown and Waller

(1986), as well as Walker and Richardson (1986) contend that replication of grazing treatments at one stocking rate is essential, grazing experiments that forfeit replication and use multiple stocking rates allow the researcher to examine treatment effects at several stocking rates. Covariance analysis then can be used to detect differences between regression coefficients, indicating a treatment x stocking rate interaction. Riewe (1961) also stressed that multiple stocking densities should be used for each treatment, forfeiting replication. Replications are used primarily to remove the effect of soil differences between replications and to serve as a basis for measuring experimental error. Bransby (1982) supported the use of multiple stocking densities, and using regression, or covariance analysis, to determine differences between treatments. Hart (1972) also suggests that in certain cases, grazing each treatment at several intensities may be preferable to replication. Bransby (1982) suggests using four to six stocking rates for each treatment instead of replication. The trade-off appears to be that non-replicated grazing designs offer the ability to characterize treatment effects over a wider range of grazing intensities, whereas replicating grazing treatments allows researchers to quantify experimental error. Ultimately, the optimal experimental design will be determined by the treatments being applied, resources available, and the type and amount of information desired.

Set-Stocked vs Variable Stocking Rate Grazing Systems

Most grazing research uses one of two common techniques for controlling stocking rates, known as set stocking and variable stocking, or put-and-take (P&T). Set-stocking systems maintain a fixed number of animals per unit area throughout the entire season; "put-and-take" systems add or remove animals during the season, usually in relation to the amount of available forage/steer. Set stocking rates are pre-determined, whereas in the P & T system, season-long stocking rates are not known until the trial is completed and can be quite different than anticipated. Set stocking rates can be thought of as a P & T system in which the adjustment of animal numbers is zero. Put-and-take systems are popular because many scientists believe that it is the best way to obtain reliable, unbiased estimates of the seasonal production curves of various factors such as forage species, species mixtures, and fertility treatments. Burns et al. (1970) report little difference in experimental errors when comparing traditional set stocking rates vs put-and-take systems. By using P & T systems, researchers can maintain similar forage mass across all treatments despite differences in forage production by adding or removing cattle.

Small-Package Energy Supplements for Cattle Grazing Winter Wheat

Energy supplements can also be used to influence animal performance and grazing pressure by stocker cattle grazing winter wheat. Although performance of cattle grazing winter wheat traditionally is high (.68 to 1.13 kg/d), certain additives can improve animal performance further. Part of this improvement comes through improving utilization of the nutrients associated with high quality wheat forage. Supplementation programs may help optimize the relative size of ruminally available nitrogen and energy pools. Hogan and Weston (1970) and Hogan (1982) discussed the necessity of balancing levels of nitrogen and digestible organic matter for efficient microbial protein synthesis and improved utilization of dietary nitrogen. Hogan (1982) suggested that as forage DOM:CP ratios drop to 3:1 or lower, ruminal ammonia concentrations increase dramatically, indicating that forage nitrogen utilization is reduced by a ruminal energy deficiency. Wheat forage commonly contains 75% digestible dry matter and 25 to 30% crude protein (Horn, 1984), with a DOM:CP ratio of 2.5:1 to 3:1. Additionally, Vogel et al. (1987) and Zorrilla-Rios et al. (1985) reported that 50 to 75% the CP fraction of wheat forage disappeared rapidly in the rumen, creating a large ruminal nitrogen pool in relation to readily available energy (digestible organic matter). Providing an energy supplement may improve performance based on the theory that the quantity of microbial crude protein that can be synthesized in the rumen is limited by the amount of available energy, as suggested by Owens and Zinn (1988). Forbes et al. (1966, 1967) and Lake et al. (1974a,b) reported that providing barley and corn supplements, respectively, increased nitrogen retention and weight gain of steers grazing high quality forages. Thus, providing an energy supplement for cattle grazing winter wheat potentially may improve nitrogen utilization and animal performance.

Effects of Ionophores on Weight Gain of Stocker Cattle.

Providing a supplement allows producers to supply additional feed additives, e.g., minerals, ionophores, and(or) antibiotics, to improve feed efficiency and daily gains by grazing cattle. Several trials have been conducted to determine the effects of ionophore on weight gains of grazing cattle. Oliver (1975) fed various amounts of monensin to steers grazing coastal bermudagrass during a 140-d summer grazing program. Treatments included an unsupplemented negative control or supplemented treatments offering .91 kg/day of a ground, pelleted corn supplement containing either 0 (control), 25, 50, 100, or 200 mg monensin. Providing the carrier supplement alone increased daily gains by approximately .10 kg/day; monensin-containing supplements increased daily gains by .17 kg/day over unsupplemented cattle. Potter et al. (1976) reported similar results in a series of trials evaluating monensin intakes of 0, 50, 100, 200, 300 and 400 mg/day. The addition of 200 mg monensin/day increased ADG by 17% (.1 kg/day) over steers receiving the control supplement. Results from Oliver (1975) and Potter et al. (1976) indicate that an optimum dosage of monensin is approximately 200 mg/day. Porter et al. (1986) also summarized 47 trials evaluating the effect of monensin fed at 200 mg/day on daily gains of cattle grazing a variety of forages or offered a wide range of harvested forages. In general, the carrier supplement and monensin each increased daily gains by .09 kg/day for an average performance increase of .18 kg/day for the combination. Horn et al. (1981) reported that the addition of monensin at 200 mg/day increased ADG of stocker cattle grazing winter wheat by .08 kg over cattle receiving the supplement without rumensin. In a trial involving steers and heifers grazing fescue during the winter and receiving .91 kg/day of a milo supplement with or without monensin, addition of monensin at 200 mg/day increased daily gains by .14 kg/day during the 112-day trial (Apple and Gill, 1977). Additional trials involving cattle grazing pasture or fed forage diets in confinement all show that daily gains were increased when monensin was fed at 200 mg/day (Boling et al., 1977; Steen et al., 1978; Males et al., 1979). Providing ionophores has consistently increased daily gains of cattle grazing all types of forages, as well as cattle in confinement receiving forage-based diets. In the trials summarized here, the effects of the carrier supplement and of the ionophore were equal and additive, each increasing ADG by .09 to .1 kg/day.

Development of a Small-Package, Monensin-Containing Energy Supplement.

Based on the increased gain obtained from a supplemental ionophore, Horn and Phillips (1985; unpublished data) developed a wheat pasture mineral supplement containing cottonseed meal, wheat middlings, and monensin or lasalocid with a targeted consumption of .23 kg/day. Daily supplement consumption averaged .13 and .24 kg/day, respectively, for monensin and lasalocid supplements. Results from this trial led to the development of a small package, self-limiting monensin-containing energy supplement designed for cattle grazing winter small grains pastures. The final supplement formulation was predominantly a milo-based supplement containing wheat middlings, molasses, limestone, dicalcium phosphate, and 4% salt used as an intake limiter. Desired daily supplement intake was .91 to 1.36 kg/steer, with the supplement designed to: 1) balance the DOM:CP ratio of wheat forage as suggested by Hogan (1982), 2) supply additional calcium for growth of stocker cattle, and 3) provide a means from a management standpoint of supplying grazing stocker cattle with other feed additives, e.g., ionophores, antibiotics, or bloat-preventatives to improve animal performance. Monensin was included at 165 mg/kg, resulting in a desired daily monensin intake of 150-225 mg/steer. Individual trial results, as reported by Horn et al. (1990; 1992) and Beck et al. (1993), resulted in consistent increases in steer gains of .20 to .24 kg/day over steers receiving a mineral supplement alone. Muller et al. (1986) reported similar increases in daily gains of stocker cattle in a summary of several trials where energy supplements containing monensin were hand-fed every other day or provided as a self fed (salt-limited) dry supplement. Daily gains also were increased .25 kg/day by providing a monensin-containing energy supplement fed every other day to stocker cattle grazing wheat pasture (Andrae et al., 1994).

Although previous trials using the small-package, self-limiting, monensin-containing energy supplement produced consistent improvements in daily gain, supplement intakes still were quite variable. Further development of the supplement was focused on evaluating the factors affecting supplement intake. The three supplement ingredients that are believed to influence supplement intake include salt, monensin, and magnesium oxide. Numerous trials have described the effects of salt level on diet and supplement intakes; however, little information is available concerning the effects of magnesium oxide and monensin on intake of self-limited supplements.

Effect of Magnesium Oxide in Wheat Pasture Supplements

Research on the chemical composition of wheat often has focused on factors responsible for metabolic disorders such as grass tetany (Stewart et al., 1981; Bohman et al., 1983). These metabolic disorders are restricted almost entirely to mature cows in the latter stages of pregnancy or nursing calves. Growing calves grazing winter wheat forage traditionally meet their magnesium requirements (.10% of DM; NRC, 1996) throughout the winter grazing season, with wheat forage Mg levels ranging from .21 to .15% (Horn 1984). Although the dietary supply of Mg may be adequate, absorption of Mg can be reduced by high K concentrations associated with wheat forage. House and Van Campen (1971) reported that providing 60 g of KCl reduced Mg absorption in sheep fed a semi-purified diet. Additionally, Mayland et al. (1976) suggested that the dietary availability of magnesium may be reduced by high forage concentrations of N, K, and fatty acids. Magnesium absorption was increased by feeding additional soluble carbohydrates and(or) ionophores (Fontenot et al., 1989). While including Mg in wheat pasture supplements may be justified, little is known concerning the relationship between magnesium concentration of supplements and supplement intake. In a palatability trial involving Merino sheep, a magnesium oxide (MgO) solution was sprayed directly on chopped wheat hay at levels ranging from 1.6 to 60g/kg of hay. Preference and rate of intake decreased as MgO level increased (Gherardi and Black, 1991), indicating that the addition of MgO decreased palatability of the wheat straw. McClure and Fontenot (1985) reported that the addition of magnesium to a liquid urea-molasses supplement decreased intakes by approximately 25%. Reasons for the decreased intake were not discussed, so it is difficult to determine if the decreased intake was due to decreased palatability. Zhu et al. (1991) reported that intake of poured feed blocks was reduced by the addition of magnesium oxide, but they attributed the reduced intake to the increased hardness of the block as magnesium oxide concentration increased.

Based on the limited amount of information available, it is difficult to determine whether the decreased intakes observed by McClure and Fontenot (1985) and Gherardi and Black (1991) were due to decreased palatability or some chemostatic effects of increasing magnesium intake. While the addition of magnesium oxide appears to restrict diet intake, injections of calcium and magnesium into the cerebral spinal fluid of sheep and goats can elicit feeding (Seoane et al., 1975); however, it is difficult to elevate Mg levels in the body. Blood magnesium levels remain relatively constant despite fluctuations in diet magnesium level. Ammerman et al. (1972) reported that plasma magnesium levels alone are a poor indicator of magnesium absorption because magnesium absorbed in excess of need is readily excreted through the urine. In a more recent study, the magnesium absorption increase caused by the addition of ionophores to the diet was offset by increased urinary excretion, resulting in no difference in Mg retention (Kirk et al., 1994).

Effects of Ionophores on Intake

Monensin also may influence intake of the self-limited energy supplement described above. Ionophores have been used successfully in wheat pasture grazing operations, improving animal performance and decreasing incidence and severity of bloat (Branine and Galyean, 1990). Although all ionophores (monensin, lasalocid, and laidlomycin propionate) appear to work through similar mechanisms at the molecular and cellular level, there are still differences in animal responses between ionophores. Of the ionophores, monensin appears to be more efficacious than lasalocid in reducing the incidence and severity of legume and wheat pasture bloat (Bartley et al., 1983; Paisley and Horn, 1998) despite similar effects on ruminal fermentation. Additional differences exist between ionophores concerning their effects on feed intake.

Intake of Feedlot Diets. While all ionophores have the potential to affect feed intake, the exact mechanism still is unknown. Monensin does appear to decrease intake of feedlot rations, as reported by Elanco Products, Co. (1975, as reported by Vogel, 1995). In the 19 trials evaluated in their report, monensin decreased feed intake by 3.2 to 10.7%. Feed intake also decreased as monensin concentration was increased from 5 to 30 g/ton. Goodrich et al., (1976) reported similar findings in a 29-trial summary. Feed intake decreased in proportion to the amount of monensin fed in the diet, with feed intake reduced by 8.1% at the highest approved level of monensin (30 g/ton). Lasalocid and laidlomycin propionate also appear to affect feed intake, but not to the same degree as monensin. Brandt (1982, as reported by Vogel, 1995) reported that DM intake of steers receiving lasalocid decreased as level of lasalocid increased; however, the intake reductions were smaller than the reductions associated with feeding monensin. Feed intake was only 2.5% lower for steers receiving 30g of lasalocid/ton of feed compared with control steers. Laidlomycin, in contrast, appears to have little effect on feed intake when fed within the approved concentrations for feedlot diets (Syntex Animal Health, 1994, as reported by Vogel, 1995). In addition to intake differences between ionophores, feed intake responses also are dependent upon energy density, or concentrate level, of the diet. Vogel (1995) summarized several feedlot trials between 1984 and 1994 and evaluated feed intake, daily gain, and feed efficiency responses for monensin, lasalocid, and laidlomycin propionate. The intake effects of laidloymcin propionate appeared to be unaffected by dietary energy level, whereas the depression in intake associated with monensin and lasalocid decreased as concentrate level of the diet increased. Overall, the depression in feed intakes were not as severe as those reported by Elanco Products Co. (1975), Goodrich (1976), or Brandt (1982). Vogel (1995) and Parrott (1992) attributed the more recent, smaller intake reductions to the higher concentrate levels of modern feedlot diets.

Effect of Ionophore on Forage Intake. While ionophores decrease feed intake of feedlot cattle, ionophores offered to grazing cattle via small amounts of a grain supplement (Horn et al., 1981; Andersen and Horn, 1987; Branine and Galyean, 1990; Ward et al., 1990), protein supplement (Crosthwait et al., 1979; Deswysen et al., 1987), molasses-mineral block (Horn et al., 1978), or ruminal bolus (Davenport et al., 1989; Frederickson et al., 1993) have not affected forage intake. Forage quality reported in these trials ranged from dormant native range to winter wheat pasture.

Effect of Monensin on Supplement Intake. Although providing ionophores to grazing livestock does not appear to restrict forage intake, the addition of monensin to salt-limited energy and(or) protein supplements, as well as free-choice mineral mixtures may reduce intake of the supplement. In a series of nine trials conducted to evaluate the efficacy of monensin when added to salt-limited energy supplements, Muller et al. (1986) found that self-limited supplements containing monensin required approximately 50% less salt to restrict intakes to the desired level. The addition of monensin also reduced the number of supplement formulation changes required to maintain supplement intakes. Similarly, Gulbransen and Elliot (1990) found that increasing the concentration of monensin reduced consumption of molasses-urea range supplements. The inclusion of 120 mg of crystalline monensin/kg molasses reduced molasses supplement intake by 40%, while the addition of 120 mg/kg of granular monensin reduced molasses intakes by approximately 30%. In both cases, monensin appeared to be more effective than urea at limiting molasses consumption. Berger and Clanton (1979) reported similar results with self-limiting protein supplement containing salt or salt plus monensin. Less salt was needed to limit consumption of the supplement containing both monensin and salt. Monensin also has proven to be effective in reducing intake of supplements offered to sheep (Norris et al., 1986) or sheep and goats (Huston et al., 1990). Finally, monensin has decreased intake of free-choice mineral mixture for steers grazing native grass pastures. The addition of monensin at 1620 g/ton of mineral reduced mineral consumption by 36% (3.4 and 5.3 oz/day, respectively for monensin and control supplements (Brazle and Laudert, 1998).

While ionophores appear to consistently reduce intake of the carrier feed, whether in a feedlot ration or small package supplement, the mechanism behind this reduction still is unknown. Several trials have been conducted to determine how monensin affects feed intake. Baile et al. (1979) administered 250 mg monensin over a six hour period either by ruminal infusion or by mixing it in the feed to determine if monensin palatability was responsible for reduced feed intake. Following the six hour period, steers were offered ad-libitum feed without monensin. Steers receiving the monensin-containing feed ate less during the 6 hour period, and compensated by eating more of the control diet, suggesting that monensin reduced diet palatability. However, steers receiving monensin directly into the rumen also exhibited reduced feed intake, suggesting that additional factors were involved with decreasing feed intake. Additional ionophore factors relative to the mechanism by which ionophores affect feed intake have been summarized by Vogel (1995). These factors may include increased propionate production, ionophore effects on blood glucose and free fatty acid concentrations, and an altered secretion of insulin.

Effects of Ionophores on Feed Intake Variation. The addition of monensin to feedlot diets has been shown to reduce day-to-day variation in feed intake (Britton et al., 1991; Stock et al., 1995). The importance of a reduced feed intake variation was addressed by Galyean (1992) who purposely altered feed intake variation in a feedlot trial. Varying feed intake by 10% each day resulted in negative effects on animal performance and feed efficiency. Daily gains were decreased by 6.5% while feed efficiencies were increased by 6.9% during the 84-day trial. Similarly, Stock et al. (1995) reported that increasing the monensin level of high concentrate diets fed to Holstein calves from 30 to 40 g/ton decreased digestive death loss from 2.39% to .94%. While feed intake variation is an important concern in growing and finishing rations fed in drylot, supplement intake variation may also be an important concern for grazing programs. Andrae (1994) monitored individual supplement intake by steers grazing winter wheat and fed a supplement every other day. Steers were then grouped into low, medium, and high supplement intake variation groups based on each animal's intake patterns during the 83-d trial. Steers with low supplement intake variation had higher daily gains than steers with high variation, suggesting that supplement intake patterns can affect the animal's response to supplementation programs.

Wheat Pasture Bloat

An additional factor affecting animal performance of cattle grazing winter wheat is frothy bloat. Bloat can have potentially devastating effects on animal health (Horn et al., 1981) if cattle are not monitored closely, especially when cattle are first placed on wheat pasture, and in the late winter growth period when the composition of wheat pasture changes rapidly. Although annual death losses from wheat pasture bloat have been estimated at 2 to 3%, they can be as high as 20% (Howarth and Horn, 1983). Potential causes of frothy bloat in grazing animals can be categorized into three areas: plant, animal, and ruminal factors.

Animal Factors

Variation in incidence and severity of bloat between animals grazing the same pasture may be partially related to animal factors such as differences in diet selection, forage intake and saliva production. The role of saliva in the initiation and maintenance of stable frothy bloat has been quite controversial. Weiss (1953) suggested that the formation of froth was correlated positively with the viscosity of the ingesta. Intake of lush, succulent forages was associated with reduced salivary rate, which increased the viscosity of ingesta and lead to bloat; however, research conducted by Jacobson et al. (1957) disagreed, indicating that in animals fed a bloat-provoking diet in drylot, viscosity indexes of ingesta were not associated closely with frothy, feedlot bloat. Attempting to characterize physical properties of ruminant saliva, Jones and Lyttleton (1972) collected salivary mucoprotein and esophageal mucin, and compared the foaming properties of these secretions with protozoal proteins. While both animal secretions produced stable foams, they were relatively weak when compared with the foams derived from protozoal proteins. Mendel and Boda (1961) reported that bloat-susceptible cattle secreted less saliva during both resting and feeding than unaffected cattle. VanHorn and Bartley (1961) showed that addition of saliva to frothing rumen contents in vitro released gas from the foam, indicating that saliva had antifoaming qualities, which was confirmed by Bartley and Yadava (1961). Animals highly susceptible to bloat may secrete less saliva and(or) have more active populations of mucinolytic microorganisms, as reported by Mishra et al. (1967), than animals with lower susceptibilities. Saliva, while highly viscous, probably has little effect on the formation of frothy bloat; however, increased saliva production still may affect formation and stability of frothy bloat through it's potential anti-foaming characteristics, buffering capabilities, and effects on rate of passage. While increased feed intake appears to increase the incidence of bloat, Hall et al. (1988) reported that in a comparison of bloating and non-bloating steers, non-bloating steers had higher intakes prior to bloating. Perhaps the lower feed intakes of bloating steers may reflect slower rates of passage and increased ruminal fill, both of which are conducive, or related, to bloating animals. Additionally, Johns (1954) and Hancock (1954) reported that the rate of eating was not important in determining susceptibility to bloat. While chewing and the release of plant proteins has been linked to formation of foam (Bryant, 1964), rate and extent of chewing has not been linked directly to the occurrence of bloat. Related factors concerning intake may cancel each other. More rapid intakes may increase ruminal fill, but also result in less chewing and therefore a slower release of plant proteins. Slower intakes are associated with more deliberate chewing which may release more soluble carbohydrates and proteins; however, chances of bloat are reduced by increased saliva flow and rate of fluid passage combined with slower forage intake. While no one doubts that animal variation plays a part in bloat susceptibility, it is difficult to detect any overriding animal factors affecting bloat potential.

Plant factors

Additional confusion surrounds specific plant factors that contribute to the formation and stability of foam in the rumen. In general, bloat provocative forages are actively growing, highly digestible species with high protein contents. These include temperate legumes such as red clover, white clover, persian clover, and alfalfa as well as small grains and cool season annual and perennial grasses such as ryegrass and wheat. Bloat is thought to occur when highly digestible feeds are degraded and fermented rapidly. Rapid fermentation can occur when feeds are ground very finely (Cheng and Hironaka, 1973) or when rapidly growing, succulent forages are consumed. In grazing livestock, bloat is assumed to be a result of increased concentrations of soluble proteins and(or) carbohydrates associated with the rapidly growing forage, as well as a more rapid release of plant cell contents in the rumen that leads to a high rate of ruminal gas production. Traditionally, bloat of stocker cattle grazing winter wheat pastures in the

Southern Great Plains occurs during November and in late February to early March, when the wheat is succulent and growing rapidly. Horn et al. (1977) collected wheat forage samples from Oklahoma wheat pastures with high and low occurrences of bloat. Forage samples from bloat-provocative pastures contained less dry matter and neutral detergent fiber but higher concentrations of soluble protein nitrogen and soluble nitrogen. Soluble carbohydrate levels of bloat-producing forage samples were numerically lower, but not different, from samples where bloat was not observed. Soluble protein fractions are believed to be a very important contribution to legume bloat. Early research on legume bloat focused on determining specific proteins involved in the formation and stability of foam. Proteins were divided initially into fraction I and II proteins on the basis of molecular size (Singer et al., 1952). Fraction I protein is a homogenous protein later identified as the enzyme ribulose diphosphate carboxylase (Trown, 1965) with fraction II a mixture of all soluble leaf proteins other than fraction I. Fraction I proteins were believed to be responsible for formation of stable foam (Miltimore et al., 1970); however, this theory was subsequently questioned by Howarth et al. (1973). Jones and Lyttleton (1972) suggested that both fraction I and II proteins play roles in the formation of stable foams. Additional plant compounds believed to influence formation of froth include tannins and saponins; however these compounds may not be as important in wheat pasture bloat as legume bloat. Kendall (1966) showed that foam production in vitro was inhibited by tannins. The ability to foam was restored by the addition of PVP, a compound that binds tannins. Kendall postulated that tannins, such as those associated with non-bloating legumes, may reduce the amount of stable foam produced in the rumen. Recent research has focused on specific chloroplast proteins believed to create stable foams. Majak et al. (1983, 1985) and Hall (1988) showed that ruminal chlorophyll concentrations (an indicator of chloroplast levels) were higher in ruminal contents of bloating than non-bloating animals.

In addition to soluble protein, mineral content of the forage also has been related to metabolic disorders of animals grazing winter wheat. Turner (1981) observed that the K:Na ratio of ryegrass and clover samples from pastures where animals had a high incidence of bloat were nearly twice has high as samples taken from pastures with low occurrences of bloat. Stewart et al. (1981) took forage samples throughout the growing season for three years at two locations, Bushland, Texas and El Reno, Oklahoma. They found that Ca and Mg levels remained fairly constant throughout the growing season; however, K concentrations increased dramatically within very short time periods when wheat was rapidly growing. While forage K levels have not been directly related to occurrence of bloat, K increased during the same time that wheat becomes most conducive to bloat.

Ruminal factors

Perhaps even more important than the mineral composition of the grazed forage is the relative ratios of cations ingested by the animal and present in the rumen. While a majority of bloat research has been focused on identifying organic substances that may contribute to bloat formation (Clarke and Reid, 1974; Majak et al. 1985), recent attention has focused on chloroplast proteins (Majak et al. 1983, 1986) and the colloidal properties of stable foams. Because chloroplast particles are negatively charged (Junge 1977), ions present in rumen fluid might affect their dispersion, aggregation, or suspension as a colloid, and the relative concentrations of monovalent and divalent cations may influence the stability and strength of foams. Original research investigating the coagulation of soil colloids (Vershinin et al., 1966) ranked cations by their ability to suspend and coagulate soil colloids composed of negatively charged particles. Rankings, in order of increasing ability to maintain soil colloidal suspensions, were: Li, Na, NH_4, K, Rb, Ce, Mg, Ca, and Ba. The ability to suspend colloids is a function of both the valence of the cation and its atomic weight (i.e., radius). Similar to colloidal suspensions of soils, divalent and trivalent ions can form bonds with two or three negatively charged protein (chloroplast) particles, thereby creating a more stable foam compared with sodium, a monovalent ion. Smith and Woods (1962) reported that spraying legumes with Ca and Mg salts increased severity of bloat, whereas adding mineral chelating agents reduced the severity of bloat. Hall et al. (1988) measured pre-feeding ruminal mineral concentrations in bloating and non-bloating animals over a two year period. They found that Ca, Mg and K concentrations (Meq/L) were significantly higher and Na levels significantly lower in bloating animals. Similarly, Majak and Hall (1990) reported that bloat prone animals had lower Na concentrations, but higher K concentrations that less susceptible animals. They commented that the shift in Na and K concentrations may be partially responsible for the increase in bloat susceptibility, and suggested the potential use of Na supplementation to reduce the chances of bloat. Cheng et al. (1979) reported that adding 4.0% NaCl to an all-concentrate, bloat-provoking feedlot diet, while increasing ruminal passage rate, also decreased rumen fluid viscosity, and appeared to alter ruminal fermentation patterns. The addition of salt reduced the production of slime capsules by rumen bacteria and decreased microbial cell lysis, both of which contribute to the increased viscosity that leads to bloat.

The potential effects of bacterial and protozoal polysaccharides and proteins on the development of stable foam, and occurrence of bloat has been researched extensively, as summarized by Clarke and Reid (1974). Not only do polysaccharides and proteins secreted by ruminal microbes affect the viscosity of ruminal fluid (Cheng et al., 1976a), but intracellular contents of lysed cells also may increase the viscosity of ruminal fluid, especially with feedlot bloat (Cheng et al., 1976b).

The occurrence of frothy bloat in grazing livestock is initiated primarily by a rapid release of plant cell contents, leading to a rapid fermentation, when forages are lush and rapidly growing. In the case of winter wheat pasture, bloat usually occurs when wheat is rapidly growing. Rapid growth also is associated with a concurrent decrease in dry matter and NDF (Horn et al., 1977). Other factors, while not directly responsible for the initiation of bloat, may contribute to the stability and strength of ruminal foam. These factors include individual susceptibility of the animals, relative populations of bacteria and protozoa, pre-feeding chlorophyll levels in the rumen, and relative concentrations of cations in the rumen.

Ionophores and frothy bloat

Aside from improving performance of cattle grazing winter wheat, ionophores reduce the incidence and severity of bloat (Bartley et al., 1983; Grigsby 1984; Branine and Galyean, 1990). Ionophores, specifically monensin and lasalocid, have multiple effects on ruminal fermentation. As summarized by Bergen and Bates (1984), these include:

1. Shift in acetate-propionate ratio toward more propionate.
2. Some increase of lactate to propionate production via the acrylate pathway.
3. Decreased ruminal protein breakdown and deamination; lower ruminal ammonia-N

4. Primary H^+ or formate producers, gram positive organisms, are inhibited
5. Decrease in methane production primarily due to lowered availability of H_2 and formate and depressed interspecies H_2 transfer
6. Depression of lactic acid production under acidosis inducing conditions.
7. Gram negative organisms, of which many produce succinate (source of propionate) or possess capacity for the reductive tricarboxilic acid cycle to use bacterial reducing power, survive.
8. Some evidence for depressed rumen content turnover
9. A mild inhibition of protozoa
10. Decrease in rumen fluid viscosity in bloated animals
11. Depressed growth yield efficiency of the ruminal microbes.

Although ionophores have been shown to reduce bloat , some of the direct and indirect effects of ionophores on ruminal fermentation and forage degradation potentially could be conducive to bloat. For example, plant proteins, specifically type I and II proteins (Jones and Lyttleton; 1972), as well as chlorophyll levels (Majak et al. 1983, 1986) have been shown to increase the formation of stable foam in the rumen; however, monensin decreases ruminal degradation of plant protein (Schelling et al., 1977; Poos et al., 1979), this potentially could lead to increased formation of stable foams. In addition, monensin has been shown to cause a decrease in intracellular K+ and an increase in intracellular Na+ of Streptococcus bovis cultures (Russell, 1987), resulting in increased ruminal K+ concentrations and decreased ruminal Na+ concentrations (Paisley and Horn, 1998). As reported by Hall et al. (1988) and Majak and Hall (1990), animals with higher ruminal K+ concentrations and lower Na+ concentrations are associated with greater susceptibility to bloat. The reduction in incidence and severity of legume and wheat pasture bloat (Bartley et al., 1983; Branine and Galyean,, 1990; Paisley and Horn, 1998), despite unfavorable changes in protein digestibility and cation concentrations, indicates that ionophores reduce the incidence and severity of bloat through alternate mechanisms.

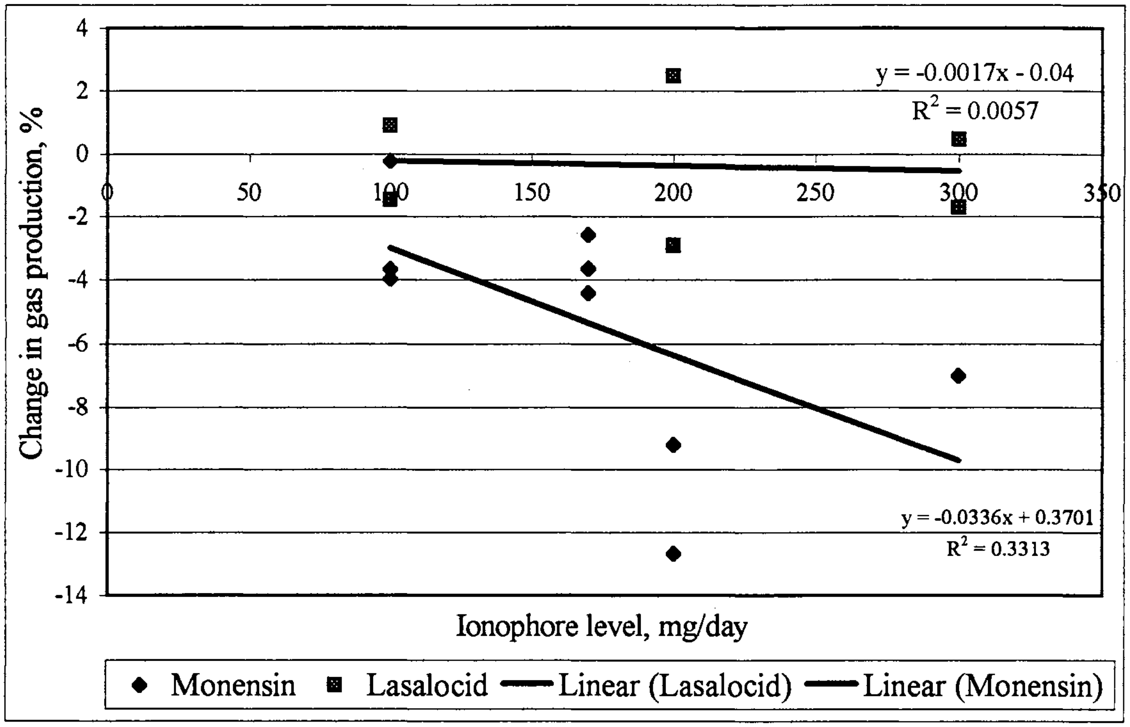
Additional effects of ionophores on ruminal fermentation may be responsible for the reduction in incidence and severity of bloat. For instance, a decrease in rumen fluid viscosity potentially could reduce the formation of a stable foam in the rumen. The incidence of wheat pasture bloat also may be due to reduced initial rate of methane production (Thornton and Owens, 1981), or overall methane production, as reported by Horn et. al. (1981). In a brief summary of trials evaluating the effects of ionophores on ruminal fermentation patterns of steers grazing winter wheat (Branine and Galyean., 1990; Davenport et al., 1989; Andersen and Horn 1987; Horn et al., 1981; Paisley and Horn, 1998), steers receiving a supplement containing monensin had a .7 to 19.1% less methane production compared with steers receiving a control supplement alone (Table 1). Methane production was based on calculations of Owens and Goetsch, (1988) where methane and carbon dioxide production is estimated using relative molar proportions of acetate, propionate and butyrate formed per unit of glucose fermented. Total gas production was decreased by .2 to 12.7%. Lasalocid did not appear to affect methane and total gas production to the same extent. When methane and total gas production was plotted against monensin dosage (mg/day), higher monensin levels resulted in greater reductions in gas production (Figure 2). The reduction in incidence and severity of bloat may be partially related to these decreases in total and(or) rate of gas production.

While research indicates that forage intake is unaffected by the addition of ionophores (Andersen and Horn, 1987; Branine and Galyean 1990, Davenport et al., 1987; Horn et al., 1981), the effects of ionophores on day-to-day variation of forage intake have not been determined. Ionophores have been shown to decrease daily variation in feed intake of feedlot diets (Britton et al., 1991; Stock et al., 1995), suggesting that in addition to reducing gas production, ionophores may reduce the incidence and severity of bloat by decreasing variation in forage intake.

Table 1. Summary of the effect of ionophores on molar proportions of VFA's and calculated gas production in steers grazing winter wheat.

		Relative percentages of VFA's				% Decrease	Calculated gas prod. mmol			Dec. in CH_4	Decrease in
		Acetate	Propionate	Butyrate	A:P ratio	in A:P ratio	Methane	CO_2	CH_4+CO_2	Prod., %	gas prod, %
Branine and Galyean, 1990											
Early April	Grain	59.2	20.7	15.8	2.86		32.33	58.48	90.80		
	170 mg Monensin	59	22.3	13.9	2.65	-7.49	30.88	55.93	86.80	-4.49	-4.41
Late April	Grain	59.6	19.9	15.4	2.99		32.53	57.88	90.40		
	170 mg Monensin	61.1	20.1	13	3.04	1.50	32.03	55.08	87.10	-1.54	-3.65
Mid-May	Grain	65.1	18.9	12.3	3.44		33.98	55.73	89.70		
	170 mg Monensin	65.2	19.9	11.1	3.28	-4.88	33.18	54.23	87.40	-2.35	-2.56
Davenport et al., 1989											
Early February	Control	62.8	21.2	11.7	2.96		31.95	54.25	86.20		
	100 mg Monensin	61.6	20.7	12.2	2.98	0.46	31.73	54.28	86.00	-0.70	-0.23
Early March	Control	63.7	17.5	13.4	3.64		34.18	56.33	90.50		
	100 mg Monensin	63.1	19.4	11.9	3.25	-10.64	32.65	54.25	86.90	-4.46	-3.98
Early April	Control	59.9	19	16.2	3.15		33.30	59.00	92.30		
	100 mg Monensin	59.7	20.9	14.6	2.86	-9.39	31.93	56.98	88.90	-4.13	-3.68
Andersen and Horn, 1987											
Trial 1.	Control	56.6	20.7	16.3	2.73		31.28	57.93	89.20		
	100 mg Lasalocid	58.1	20.1	14.9	2.89	5.71	31.48	56.43	87.90	0.64	-1.46
	200 mg Lasalocid	56.6	18.9	17.4	2.99	9.52	32.28	59.13	91.40	3.20	2.47
Trial 2.	Control	59.8	21	14.8	2.85		32.05	57.35	89.40		
	100 mg Lasalocid	59	21.7	15.6	2.72	-4.52	31.88	58.33	90.20	-0.55	0.89
	200 mg Lasalocid	60	21.7	13.4	2.76	-2.90	31.28	55.53	86.80	-2.42	-2.91
Trial 3.	Control	64.9	18.8	11.7	3.45		33.60	54.70	88.30		
	300 mg Lasalocid	63.4	19.8	11.7	3.20	-7.25	32.60	54.20	86.80	-2.98	-1.70
Horn et al., 1981											
Trial 1.	Control	65.86	16.4	13.28	4.02		35.47	56.95	92.42		
	200 mg Monensin	59.14	25.03	10.78	2.36	-41.16	28.70	52.00	80.70	-19.08	-12.68
Trial 2.	Control	56.21	22.79	14.15	2.47		29.48	55.03	84.51		
	200 mg Monensin	54.98	28.24	10.88	1.95	-21.06	25.87	50.87	76.74	-12.25	-9.19
Paisley et al., 1998											
	Control	60.69	19.21	14.06	3.16		32.57	56.24	88.81		
	300 mg Monensin	59.56	22.05	11.51	2.70	-14.50	30.02	52.56	82.58	-7.83	-7.01
	300 mg Lasalocid	61.5	18.43	13.86	3.34	5.62	33.07	56.15	89.22	1.54	0.46

Figure 2. Effect of ionophore level on calculated gas production in steers grazing winter wheat.



Ionophores, especially monensin, appear to be efficacious in reducing the incidence and severity of wheat pasture bloat. While the exact mechanism is not completely understood, possible factors include reducing the initial rate of gas production in the rumen, as well as reducing methane production, as calculated by using the relative molar proportions of acetate, propionate and butyrate. Additional factors may include altering the bacterial population, helping to reduce ruminal fluid viscosity, and perhaps reducing day-to-day variation in forage intake.

Summary of Review of Literature

To maximize returns from wheat pasture grazing and grain operations, it is important to determine the factors affecting forage and grain production of the wheat crop, as well as those factors that affect animal performance, such as stocking rate, supplementation strategies, and wheat pasture bloat. Research indicates that forage and grain production are affected adversely when wheat is severely grazed during the winter. However, an increased stocking density generally increases beef production per acre. Therefore, it is important to determine the stocking density where net returns are maximized in wheat pasture grazing and grain operations. Supplementation programs also affect animal performance and net returns/animal. Providing energy supplements and(or) ionophores to cattle grazing high quality forages can improve animal performance, and these effects appear to be additive. Evaluating supplementation methods for cattle grazing winter wheat will help reduce feed and labor costs associated with supplementation programs while maintaining and(or) enhancing animal response to the supplement. In addition to improving performance, ionophores also reduce the incidence and severity of bloat associated with grazing lush pastures. Whether the ionophores are eliciting their effect through reducing methane production, affecting ruminal fluid viscosity, or altering relative proportions of ruminal bacterial populations is not completely understood; however, the potential benefits include reduced digestive upsets and death loss due to bloat, both of which are an important concern for stocker producers. Continued investigation of self-fed supplements, as well as the optimum ionophore levels for cattle grazing winter wheat, will help to target for maximum gain response for supplementation programs on winter wheat.

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CHAPTER III

EFFECTS OF MONENSIN AND MAGNESIUM OXIDE ON SELF-LIMITED SUPPLEMENT INTAKE AND PERFORMANCE OF GROWING STEERS GRAZING WINTER WHEAT PASTURE

S.I. Paisley, G.W. Horn and C. J. Ackerman

ABSTRACT

Two experiments were conducted to determine the effect of monensin and magnesium oxide (MgO) on intake of a self-limited supplement and live weight gain of growing steers grazing winter wheat pasture. A third experiment evaluated the effects of increasing levels of MgO on ruminal fermentation. In Exp. I and II, 44 and 48 steers, respectively, were equally allotted to 4 winter wheat pastures and stocking density was not altered in the experiments. Steers were given free access to a milo-based self-limited energy supplement containing 4.0% salt as an intake limiter. Experiment I evaluated the effects of monensin when included at either 0 or 165 mg monensin/kg of supplement (as-fed basis). Supplement was provided free-choice via self-feeders, with supplement intakes for each pasture determined by weekly weigh-back of remaining feed. The addition of monensin decreased ($P < .01$) daily supplement intake (DM basis) from 2.28 to .65 kg/steer, a 71% reduction. Daily gains were similar ($P = .95$) for both supplementation treatments during the 87-d supplementation period despite reduced supplement intakes for steers receiving monensin. Experiment II measured supplement intake and performance of steers receiving the same self-limited energy supplement containing 165 mg monensin/kg and .25, .75, 1.25 or 1.75% MgO (as-fed basis). Individual animal supplement consumption was measured using Pinpointer feeders. Supplement intake averaged .68 kg/day, and increased linearly (P = .01) with increasing levels of MgO. Steers spent an average of 15.7 minutes/day eating supplement and an average of 2.7 visits to the feeder•steer^{-1}•day^{-1}. Daily gains were not affected (P = .11) by increasing levels of MgO. Following Exp. I and II, a third experiment was conducted using 12 ruminally cannulated steers grazing winter wheat pasture and bolused daily (0800) with either 0, 12.5 or 25 g MgO via gelatin capsule. Ruminal fluid was sampled on day 10 of bolusing at 0800, 1200, and 1500 (0, 4 and 7h relative to bolusing). As level of MgO increased, there was a quadratic increase (P = .01) in total VFA production , as well as a linear increase (P = .01) in molar proportions of propionate and a linear decrease (P = .01) in the acetate:propionate ratio. Monensin limited daily intake of this self-fed energy supplement to targeted levels of .91 to 1.36 kg/steer, while increasing levels of MgO did not appear to decrease supplement intake. MgO may, however, have beneficial effects on ruminal fermentation.

(Key Words: Supplementation, Monensin, Magnesium Oxide, Wheat Pasture, Cattle.)

Introduction

Recent agricultural surveys estimate that approximately 57% of winter wheat planted in Oklahoma is grazed during the winter months, either in forage-only, or as a part of a dual-purpose grazing and grain enterprise (Epplin, 1997). Immature wheat forage is highly digestible, with in vitro dry matter digestibilities of 75 to 76% (Zorrilla-Rios et al., 1985; Vogel et al., 1987), and crude protein levels ranging from 20 to 30% during the vegetative stage (Horn, 1984). With adequate forage, stocker cattle grazing winter wheat pasture typically achieve daily weight gains of .68 to 1.36 kg/d; however, providing small amounts of an energy supplement may further enhance daily gains and nitrogen utilization. Wheat forage contains a large quantity of soluble protein and NPN (Horn et al., 1977) that create a highly soluble, rapidly disappearing N pool in the rumen. Zorrilla-Rios et al. (1985) estimated that 75% of immature wheat forage nitrogen exists as a rapidly soluable nitrogen pool with a disappearance rate of 13%/h. Providing an energy supplement in these situations may improve nitrogen utilization. Forbes et al. (1966, 1967) and Lake et al. (1974a,b) reported that providing barley and corn supplements, respectively, increased nitrogen retention and weight gain of steers grazing high quality forages. Horn et al. (1990 and 1992) and Beck et al. (1993) reported that providing a milo-based, self-limited energy supplement with a targeted daily intake of .91 to 1.36 kg•head^{-1}•day^{-1} increased daily gains of growing cattle on wheat pasture by an average of .23 kg over cattle offered mineral supplement alone during each of four wheat pasture years. In addition to improving performance, self-limited energy supplements also can provide an ionophore to decrease bloat, as well as additional minerals. The objective of this study was to determine the effect of monensin addition and MgO concentration on intake of a self-limited supplement for stocker cattle grazing winter wheat pasture.

Materials and Methods

Experiments I and II

Supplement. The supplement used in these experiments was a milo-based energy supplement containing 4.0% salt (as-fed basis) fed in meal form (Table 1). Experiment I examined the effect of monensin on intake of the self-limited supplement. Two formulations of the supplement were developed containing either 0 (Control) or 165 mg of monensin/kg of supplement (as-fed basis). Supplements were assigned to four pastures planted to hard red winter wheat (*Triticum aestivum*), resulting in two pastures per treatment. Experiment II evaluated the effects of four levels of MgO on supplement intake of individual steers. Supplement formulations in Exp. II contained 165 mg monensin/kg and .25, .75, 1.25 or 1.75% MgO (BayMag) on an as-fed basis, with one pasture/treatment. Supplement intake was measured for each steer, with 11 steers/pasture. All supplement formulations were sampled during sacking as well as each time feed was added to the feeders. Samples were composited across days within each pasture for each batch mix and analyzed for monensin and mineral content to determine actual concentrations of monensin and magnesium being fed.

Study Site. Cattle grazed four 8.1 ha pastures planted to hard red winter wheat from December 19, 1995 until April 14, 1995 (117 d, Exp. I) or from November 8, 1996 through December 20, 1996 (42 d, Exp. II). No additional salt or mineral supplements were provided during either experiment. All pastures were equipped with automatic waterers. Four Pinpointer feeders were used to measure supplement intake of individual steers after an adaptation period. In Exp. I, steers were allowed access to Pinpointer feeders beginning December 19, 1995 with actual supplement intake measured from January 17 until April 14 (87 d). During Exp. II, steers were allowed access to Pinpointer feeders beginning November 13, 1996with individual supplement intake measured from November 22, through December 20 (28 d). During both experiments, steers were allowed unlimited access to large round bales of bermudagrass (*Cynodon dactylon*) hay.

Small square bales of bermudagrass hay were hand-fed when snowfall was heavy enough to limit forage intake.

Forage mass available for grazing in each of the four pastures was determined by hand-clipping wheat forage to ground level inside nine .189 m^2 quadrants systematically selected across each pasture. Pastures were clipped on December 19, February 1, March 9, and March 24 during Exp. I, and on December 6 and January 4 during Exp. II. Forage mineral analysis was conducted on samples collected during Exp. II.

Cattle. Steers used in Exp. I and II were spring-born Angus X Hereford crossbred steers originating from Oklahoma State University beef herds. Forty four steers used in Exp. I were weighed on December 19 (227 ± 20.6 kg mean initial wt) and allotted to one of four wheat pastures (11 steers/pasture). Steers were weighed again on January 17 to coincide with collection of supplement intake data. Intermediate and final weights were measured on March 23 and April 14, respectively. The 48 steers used in Exp. II were weighed November 8 (249 ± 24.1 kg mean initial wt.) and allotted equally to four pastures. Final weights were recorded on December 20, with blood samples collected via the jugular vein using heprinized tubes during the final weighing. All steer weights were recorded after a 14-h shrink.

Experiment III

Twelve ruminally cannulated steers were allotted equally to three treatments in order to characterize the effects of increasing levels of MgO on ruminal fermentation. Steers began grazing the same winter wheat pastures used in Exp. I and II on January 30, 1997. Beginning February 7, steers received either 12.5 or 25g of MgO daily at 0800 via gelatin capsule directly placed into the rumen. Control steers were handled similarly, but were not bolused. After a ten-day adaptation period, ruminal fluid was collected from all steers at 0800, 1200 and 1500, (representing 0, 4 and 7 h relative to bolusing) to determine ruminal pH, VFA concentrations, and changes in ruminal fluid mineral and VFA concentrations relative to time of bolusing.

Laboratory analyses.

Composited supplement samples were analyzed by Elanco Animal Health Customer Service Laboratories, Corporate Center, Indianapolis, IN for monensin concentrations. Supplement, forage, and plasma mineral concentrations were determined via atomic absorption spectrophotometry. Supplement and forage samples were dried to constant weight in a forced-air oven at 55°C. Following drying, samples were ground using a Wiley mill (Standard Model 3, Arthur H. Thomas Co., Philadelphia, PA) to pass through a two millimeter screen. Two grams of supplement and forage samples were ashed at 500°C for five hours. Remaining ash then was dissolved in 10 ml of a 7.2 N HCl solution and boiled on a hot plate for 15 min. The solution then was filtered through Whatman #41 ashless filter paper into glassware that previously had been soaked for 48 h in a chromium trioxide and sulfuric acid (Chromerge) solution and rinsed with ultrapure water. Samples were diluted appropriately using ultrapure water and mineral concentrations were determined using a Perkin-Elmer Model 4000 Atomic Absorption Spectrophotometer (Perkin-Elmer, Norwalk, CN). Blood samples, collected in heprinized tubes, were centrifuged initially at 6,000xg for approximately 10 minutes. Plasma was aspirated from the collection tube and refrigerated until analysis could be performed. Plasma samples were diluted using a working solution consisting of ultrapure water containing .1% Lanthanum and .1%K, with mineral concentrations determined as described above.

Ruminal fluid samples were collected systematically from several sites in the rumen and strained through 4 layers of cheesecloth, and 100 ml were used to determine ruminal pH and subsequent VFA analysis. Immediately after measuring pH, 100 ml aliquots were acidified by adding 2 ml of a 7.2 N H_2SO_4 solution and spun at 2,000 x g for 10 min to remove large feed particles. Samples were prepared for VFA analysis by adding .05 g of meta-phosphoric acid to 5 ml aliquots of ruminal fluid for initial deproteinization and centrifuged at 20,000 x g for 10 min. Following centrifugation, approximately 2 ml of supernatant fluid was frozen for later analysis. Ruminal fluid samples were analyzed for VFA concentrations using a Perkin-Elmer Autosystem gas chromatograph (Perkin-Elmer 9000 Model Series, Norwalk, CN) with 2-ethylbutyric acid added as an internal standard. The gas chromatograph was equipped with a Megabore DB-FFAP liquid phase column (30m x .53mm) using helium at 8 ml/min as the carrier gas. Initial column oven temperature was 110°C. Following each injection, column temperature was increased by 15°C/min up to 145°C. After .5 min, temperature again was elevated at 45°C/min to a final temperature of 235°C to remove impurities between sample injections. Injection port and flame ionization detector temperatures were maintained at a constant 250°C.

<u>Statistical Analysis</u>.

All statistical analyses were conduced using the GLM procedure of SAS (1990). Steer weights, daily gains, and available forage data for Exp. I were analyzed using least squares analysis as a completely randomized design with pasture as the experimental unit. After comparing actual supplement disappearance with individual visit data obtained from Pinpointer feeders in Exp. I, it was determined that the individual intake values were inaccurate. Therefore, supplement intakes reported for Exp. I were determined from weekly weigh-back and feed records for each pasture. Supplement intakes were analyzed as a repeated measures design with treatment, week, and treatment x week included in the model.

Because supplement intakes of individual animals were measured in Exp. II, steer weights and ADG were analyzed as a completely randomized design with animal as the experimental unit. Supplement intakes were analyzed using two models. Model I included treatment, steer(treatment), day, and treatment x day as sources of variation, and was used to evaluate all 1344 intake observations (28 d x 48 steers). Steer within treatment was used as the error term to test for treatment differences. For Model II, individual supplement intakes were averaged across the 28 d intake period, and the 48 observations were analyzed with treatment as the only independent variable. In both models, pre-planned linear, quadratic, and cubic orthogonal contrasts were used to interpret the effect of increasing levels of MgO on supplement intake and animal performance.

Experiment III ruminal fluid data were analyzed using least squares analysis as a repeated measures design with treatment, steer(treatment), hour, and treatment x hour included in the model. Steer within treatment was used as the error term to test treatment effects.

Results and Discussion

Experiment I

Available forage, expressed as kg forage/ha, and forage allowance, expressed as kg forage/steer, were similar ($P > .05$; Table 2) for both supplement treatments. Available forage measurements were within the critical threshold range suggested by Redmon et al. (1995), indicating that forage availability was not affecting forage intake or animal performance. Daily supplement intakes differed ($P < .01$) across weeks during the trial, so weekly supplement intakes for each pasture, as well as estimates of supplement intake variation, are shown in Table 3 and Figure 1 .No week x treatment interactions ($P = .12$) associated with supplement intakes were detected. The greater intakes during the first part of March may have been associated with cold, wet weather. Monensin decreased ($P < .01$) daily supplement intakes from 2.28 to .65 kg/steer (Table 4), a 71% decrease. Gulbransen and Elliot (1990) found that increasing the monensin concentration of a molasses/urea liquid supplement from 0 to 120 mg/kg of supplement decreased supplement intake by 40%. Similarly, Muller et al. (1986) reported that the addition of monensin to self-fed, salt-limited supplements reduced the amount of salt needed to control intake by 25 to 50%. While monensin has been shown to reduce intake variation of feedlot diets (Stock et al., 1995), standard deviations, as well as coefficients of variation associated with supplement intake were not different ($P \geq .13$) for the two supplement formulations. Failure to detect a decrease in supplement intake variation may be due to our inability to detect treatment differences due to small sample sizes (only 2 pastures/treatment).

Intermediate and final live weights of steers were not affected ($P > .70$) by supplementation treatment. Similarly, daily gains were not affected ($P \geq .21$) during any of the grazing periods by supplementation treatment. In contrast, Horn et al. (1981) and Andersen and Horn (1987) included monensin and lasalocid, respectively, in hand-fed energy supplements for growing cattle grazing winter wheat. The addition of ionophore in those trials increased daily gains by .09 to .11 kg above steers fed an equivalent amount of supplement without an ionophore.. While supplement conversions cannot be calculated for this experiment because an unsupplemented treatment was not included, daily gains were similar for both treatments, despite differences in supplement consumption; therefore, the addition of monensin may have improved supplement conversion.

Experiment II

Wheat forage available for grazing (kg/steer), measured on December 6, 1996, was similar for all pastures, with more than adequate forage to support maximum forage intake and weight gain (Table 5). Sodium concentrations ranged from .09 to .15% across all pastures, meeting NRC (1996) requirements for growing cattle (.06-.08%). Calcium concentrations ranged from .19 to .26% of forage DM, with calcium concentrations closely matching values reported by Belyea et al. (1978) however, calcium concentrations were slightly lower than the range of .30 to .50% reported by Stewart et al. (1981) and Horn (1984). These forage calcium concentrations do not meet the Ca requirements for 227 to 272-kg steers gaining .91 kg (.40 to .56% of DM; NRC 1996). Potassium concentrations of 2.65 to 3.30% were within the ranges reported by Stewart et al. (1981) and Horn (1984) for wheat forage in December, but this range overlaps the maximum tolerable concentration of 3% of DM reported by NRC (1996). Magnesium levels (.20 to .22%) were similar to those reported Stewart et al. (1981) and Horn (1984), providing adequate magnesium for growing beef cattle (NRC 1996). Actual supplement monensin concentrations were slightly higher than calculated values for all supplements, although actual values exceeded calculated values by less than 15%. Actual supplement magnesium concentrations also exceeded calculated values by 14 to 24%, with increases getting larger as MgO level increased.

Supplement intake was affected by MgO level, with both Model I and II indicating that increasing MgO levels resulted in a linear increase ($P < .03$; Table 6) in supplement intake. This disagrees with preliminary data (Hutcheson, D., unpublished data) suggesting that MgO may serve to limit supplement intake of wheat pasture stocker cattle. Additionally, Gherardi and Black (1991) reported that the addition 1.6 to 60g MgO/kg of coarsely-ground wheaten hay severely decreased palatability when offered to Merino sheep. Orthogonal contrasts for both statistical models indicate a quadratic effect ($P = .01$) of MgO level on time spent in the feeder with treatment means of 15.5, 13.5, 13.7 and 20.2 min/d as level of MgO increased from .25 to 1.75% of supplement. Although not significant ($P > .05$), visits/day appeared to follow the same quadratic trend as minutes spent in the feeder for both Model I and II ($P = .09$ and .06, respectively). This study suggests that inclusion of MgO at levels less than 1.75% of supplement does not decrease supplement intake of steers grazing wheat pasture. In addition, including all daily supplement intake data (Model I) slightly reduced the standard error of the means for supplement intake, minutes spent eating and number of visits/d. Final weights and daily gains of steers were not affected ($P > .11$) by increasing levels of MgO. This was expected, as differences in supplement consumption were small, and the short duration of the trial limited our ability to detect treatment differences in performance. Plasma Ca concentrations were not affected ($P \geq .24$) by treatment. Similar calcium concentrations were expected, as all supplement formulations had similar Ca levels. Despite increasing supplement magnesium levels, plasma magnesium concentrations remained unchanged. Recently, Kirk et al. (1994) found that increased magnesium absorption caused by the addition of ionophores was offset by increased urinary excretion. Halse (1970) reported that urinary magnesium concentrations may be a better indicator of magnesium status than plasma concentrations.

Experiment III

No interactions were detected between MgO level and hour of sampling ($P > .10$) except for isobutyrate ($P = .03$); therefore, data are presented by main effects of MgO level and hour. As MgO increased from 0 to 25 g/d, ruminal pH and molar proportions of isovalerate decreased quadratically ($P = .02$; Table 7), while total VFA concentrations increased quadratically ($P = .01$). Additionally, linear increases ($P = .01$) in the molar proportions of propionate, and linear decreases ($P = .01$) in the acetate:propionate ratios were noted as level of MgO increased. All other molar proportions of VFAs were unaffected ($P \geq .11$) by MgO supplementation. The decreased pH and increased total VFA production indicate a ruminal response to Mg supplementation although mineral analysis indicated that the Mg concentration of the forage was in excess of requirements (.10% of DM; NRC 1996). Although dietary supply of Mg may be adequate, absorption and(or) microbial utilization of Mg may be affected by the high K concentrations associated with wheat forage. House and Van Campen (1971) reported that providing 60 g of KCl reduced Mg absorption in sheep receiving a semi-purified diet. Additionally, Ammerman et al. (1972) reported that feed intakes in sheep fed purified diets devoid of Mg were depressed. Feed intake quickly rebounded when MgO was added to the diet. In subsequent experiments (Ammerman et al., 1972), total VFA production and in vitro digestibility were depressed in sheep receiving Mg deficient diets, and both were improved when MgO was reintroduced into the ration.

All ruminal VFAs and pH were affected ($P < .05$; Table 8) by hour of sampling. Significant sampling hour effects probably are attributed to diurnal grazing behavior of steers, reflecting forage intake and subsequent ruminal fermentation patterns. Ruminal pH was lowest ($P < .05$) and ruminal VFA concentrations were highest ($P < .05$) at 0800, suggesting that forage intake peaked prior to 0800.

Implications

Monensin appears to effectively limit intake of a self-fed energy supplement for growing cattle grazing winter wheat pasture to levels that approached the target intake of .91 to 1.36 $kg \cdot steer^{-1} \cdot d^{-1}$ for this supplementation strategy. Similar weight gains were achieved with much smaller amounts of supplement as compared with greater amounts of the same supplement without monensin. Including MgO at levels less than 1.75% of the supplement did not decrease supplement intake.

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Table 1. Feedstuff and nutrient content of energy supplements (as-fed basis).

Ingredient	
Milo, Ground, %	63.3, 62.8[b], 62.3, 61.8
Wheat middlings, %	21.0
Molasses, sugarcane, %	4.8
Limestone (38%), %	4.0
Dicalcium Phosphate, %	2.6
Fine Mixing Salt, %	4.0
BayMag (Magnesium Oxide), %[a]	.25, .75[b], 1.25, or 1.75
Rumensin 80 Premix	0 or 938 g/1000 kg[b]
- - - - - - - - - - - - - - Calculated nutrient content - - - - - - - - - - - - - -	
Dry matter, %	88.7
NEm, Mcal/cwt	61.3
NEg, Mcal/cwt	37.9
Crude protein, %	9.17
Calcium, %	2.2
Phosphorus, %	.9
Magnesium, %	.49, .85[b], 1.17, or 1.56
Monensin, mg/kg	0, 165

[a]Added to achieve .25, .75, 1.25, or 1.75% magnesium oxide (as-fed basis) in Exp II.
[b]Feed ingredient and nutrient amounts for supplement used in Exp. I.

Table 2. Wheat forage mass and allowance for steers grazing winter wheat and offered a self-limited energy supplement with or without monensin[a], Exp. I.

Item	1 Control	2 Monensin	3 Control	4 Monensin
Steers/pasture	11	11	11	11
Kg forage/ha				
December19	1915	1705	1660	1709
February 1	2040	1884	2014	1946
March 9	2358	2810	2604	3181
March 24	2989	2747	2752	3043
Kg forage/steer				
December19	1557	1386	1350	1390
February 1	1659	1532	1637	1582
March 9	1917	2285	2117	2587
March 24	2430	2234	2238	2474

[a]No treatment differences detected (P > .05) in kg forage/ha or kg forage/steer.

Table 3. Daily supplement DM intake of steers offered a self-limited energy supplement with or without monensin, Exp I.

Week	Pasture 1 Control	Pasture 2 Monensin	Pasture 3 Control	Pasture 4 Monensin
Jan 17-Jan 25	2.31	.77	1.94	1.17
Jan 25-Feb 1	2.11	.66	2.65	1.09
Feb 1-Feb 8	2.08	.54	2.47	.73
Feb 8- Feb 15	1.74	.56	2.42	.48
Feb 15- Feb 23	1.43	.54	2.87	.68
Feb 23- Mar 1	1.52	.39	2.18	.48
Mar 1- Mar 8	3.49	.97	2.89	.81
Mar 8- Mar 15	3.27	.76	2.94	.74
Mar 15- Mar 22	2.69	.64	2.88	.68
Mar 22- Mar 29	1.42	.52	1.75	.51
Mar 29- Apr 5	1.70	.53	2.09	.56
Apr 5- Apr 12	1.94	.44	2.03	.43
Avg. supp. intake	2.14	.61	2.43	.70
Std. dev.	.69	.16	.42	.24
C.V.	32.21	26.40	17.39	33.90

Table 4. Supplement intake and performance of steers grazing winter wheat and offered a self-limited energy supplement with or without monensin, Exp. I.

Item	Control	Monensin	SE[a]	P<[b]
No. of steers	22	22		
Pastures	2	2		
---------------- Supplement Consumption ----------------				
Supplement intake,kg/d	2.28	.65	.064	.01
Standard dev.	.56	.20	.100	.13
Coeff. of Var	24.8	30.15	5.872	.59
------------------ Steer Peformance ------------------				
Steer wt, kg				
January 17	277	272	2.9	.35
March 23	358	355	4.13	.70
April 14	395	394	4.69	.95
Daily gains, kg/steer				
Jan 17 – Mar 23, 65d	1.25	1.29	.058	.71
Mar 23 – Apr 14, 22d	1.67	1.77	.039	.21
Jan 17 – Apr 14, 87d	1.36	1.41	.044	.48

[a]Standard error of least square means.
[b]Overall significance level for treatment.

Table 5. Wheat forage mass and mineral content, and calculated and actual monensin and magnesium concentrations of supplement offered to steers grazing winter wheat, Exp. II.

	Level of magnesium oxide, %			
Item	.25%	.75%	1.25%	1.75%
Available forage, kg/steer, December 6, 1996	1331	1324	1310	1389
- - - - - - Forage Analysis, % DM - - - - - -				
December 6, 1996				
Sodium	.10	.14	.10	.15
Calcium	.22	.19	.20	.23
Potassium	2.94	2.65	2.81	2.94
Magnesium	.20	.22	.22	.21
January 4, 1997				
Sodium	.09	.11	.09	.09
Calcium	.26	.20	.20	.22
Potassium	3.13	3.02	3.30	3.09
Magnesium	.21	.22	.21	.21
- - - - - - Supplement Analysis - - - - - -				
Monensin, mg/lb as-fed				
Calculated	165	165	165	165
Actual	175	188	182	190
Magnesium, % DM				
Calculated	.43	.70	.98	1.26
Actual	.49	.85	1.17	1.56

Table 6. Supplement intake, weight gains, and plasma mineral concentrations of steers offered a self-limited monensin-containing energy supplement with increasing levels of magnesium oxide, Exp. II.

	Level of magnesium oxide, %					Contrast[a]		
Item	.25	.75	1.25	1.75	SE[b]	L	Q	C
Model I								
Intake, $kg \cdot hd^{-1} \cdot d^{-1}$	.59	.66	.58	.88	.025	.01	.07	.07
Min. eating suppl.	15.5	13.5	13.7	20.2	.54	.03	.01	.55
Visits to feeder	2.66	2.53	2.52	3.13	.075	.16	.09	.62
Model II								
Intake, $kg \cdot hd^{-1} \cdot d^{-1}$	.59	.66	.58	.88	.073	.03	.12	.13
Min. eating suppl.	15.5	13.5	13.7	20.2	1.37	.02	.01	.53
Visits to feeder	2.66	2.53	2.52	3.13	.190	.11	.06	.57
Animal Performance								
Steer wt Nov. 8, kg	255	252	248	242	7.0	.18	.80	.96
Steer wt Dec. 20, kg	287	289	279	274	7.4	.16	.62	.62
Daily gains, kg/d 42d	.78	.90	.76	.79	.060	.74	.45	.11
Plasma mineral Concentrations								
Ca, mg/100ml	9.35	9.51	9.45	9.37	.099	.98	.24	.69
Mg, mg/100ml	4.33	4.12	4.21	4.22	.102	.57	.29	.44

[a]Observed significance level for linear (L), quadratic (Q), and cubic (C) contrasts.
[b]Standard error of the means.

Table 7. Ruminal pH and VFA concentrations of steers grazing winter wheat pasture and bolused with 0, 12.5 or 25 g MgO/d, Exp. III.

	$MgO{\cdot}hd^{-1}{\cdot}d^{-1}$				Contrasts	
Item	0 g	12.5 g	25 g	SE	L	Q
pH	6.12	5.90	5.86	.062	.01	.02
Total VFA's, mM	128.94	145.16	140.49	2.567	.02	.01
Acetate, mol/100mol	62.26	61.57	61.46	.770	.11	.49
Proprionate mol/100mol	20.12	21.03	21.15	.508	.01	.18
Acetate/propionate ratio	3.11	2.94	2.92	.110	.01	.21
Butyrate mol/100mol	12.42	12.27	12.22	.300	.38	.81
Isobutyrate mol/100mol	1.67	1.64	1.69	.074	.82	.52
Valerate mol/100mol	1.38	1.44	1.42	.064	.43	.36
Isovalerate mol/100mol	2.16	2.04	2.06	.083	.01	.02

[a]Observed significance level for linear (L), quadratic (Q), and cubic (C) contrasts.
[b]Standard error of the means.

Table 8. Effects of sampling time on ruminal pH and VFA concentrations of steers grazing winter wheat and bolused with magnesium oxide, Exp. III.

Item	Hour relative to bolusing			
	0 h (0800)	4 h (1200)	7 h (1500)	SE[a]
pH	5.70[b]	6.13[d]	6.03[c]	.030
Total VFA's, mM	155.97[d]	121.89[b]	136.73[c]	3.066
Acetate, mol/100mol	60.96[b]	62.82[c]	61.51[b]	.331
Proprionate mol/100mol	21.62[c]	20.43[b]	20.24[b]	.228
Acetate/propionate ratio	2.83[b]	3.10[c]	3.05[c]	.047
Butyrate mol/100mol	12.46[b]	11.67[c]	12.79[b]	.158
Isobutyrate mol/100mol	1.45[b]	1.67[c]	1.87[d]	.043
Valerate mol/100mol	1.52[c]	1.35[b]	1.36[b]	.036
Isovalerate mol/100mol	1.98[b]	2.06[c]	2.21[d]	.021

[a]Standard error of the mean.

[c,d,e]Means in the same row with different superscripts differ ($P < .05$)

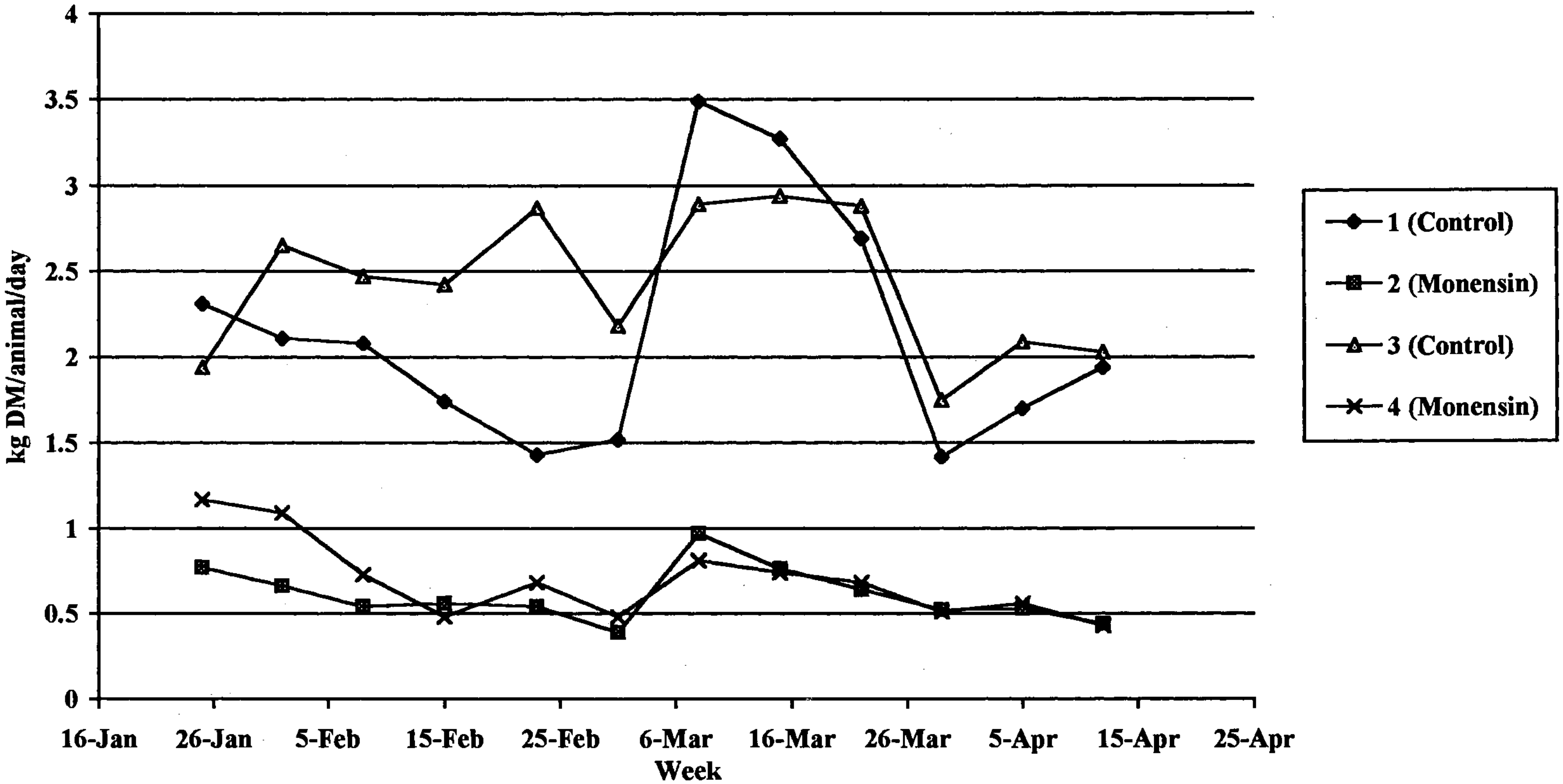

Figure 1. Weekly supplement DM intakes of steers offered a self-limited energy supplement with or without monensin while grazing wheat pasture.

CHAPTER IV

EFFECT OF IONOPHORE ON RUMINAL FERMENTATION AND OCCURENCE OF BLOAT IN CATTLE GRAZING WINTER WHEAT PASTURE

S.I. Paisley and G.W. Horn

ABSTRACT

Twelve ruminally cannulated steers (528 ± 30 kg) grazed a common wheat pasture near Stillwater, Oklahoma from January 30, 1997 through April 7, 1997 and were alloted by weight to three treatments (four steers/treatment): control (no ionophore), 300 mg monensin•steer^{-1}•d^{-1} or 300 mg lasalocid•steer^{-1}•d^{-1}. Ionophores were administered via oral bolusing with gelatin capsules to evaluate the effects of ionophores on in vitro gas production, ruminal parameters, and occurrence of bloat. No grain or mineral supplements were fed during the trial. Ruminal fluid was collected between 0830 and 0930 on three dates (March 13, 21, and 27) in an attempt to collect fluid at the time when wheat was actively growing, at or near its greatest bloat potential. Steers were observed for signs of bloat and assigned a bloat score prior to bolusing each morning from March 15 through March 28 (14 d). Steers receiving ionophores had lower (P = .04) molar proportions of butyrate than control steers. Calculated ruminal gas production (CH_4 + CO_2, moles) per mole of glucose fermented by steers receiving ionophores was 3.3% lower (P = .04) than for control steers. Ruminal sodium concentrations tended (P = .08) to be lower while potassium concentrations tended (P = .08) to be higher for steers receiving ionophores. When comparing ionophores, steers receiving monensin had higher (P < .01) molar proportions of propionate and lower (P < .01) acetate:propionate

ratios than steers bolused with lasalocid. Changes in the relative proportions of VFAs between monensin and lasalocid-bolused steers resulted in 9.2% lower ($P < .01$) methane and 7.4% lower ($P < .01$) total gas production per mole of glucose fermented (moles) for steers receiving monensin based on fermentation balance calculations. While steers receiving ionophores tended ($P < .10$) to have fewer days of bloat and lower mean bloat scores than control steers, differences between ionophores were more pronounced. Steers receiving monensin had fewer bloat days (1.0 vs 8.3; $P = .05$) and lower mean bloat scores (.05 vs .77; $P = .04$) than steers receiving lasalocid. Based on visual observation of incidence and severity of bloat, monensin appeared to be more efficacious than lasalocid for prevention of bloat.

(Key Words: Bloat, Ionophore, Beef Cattle, Wheat Pasture.)

Introduction

Two ionophores, monensin and lasalocid, if delivered in the proper dosage, typically will increase weight gains of growing cattle on wheat pasture by .09 to .11 kg/d above that of steers receiving the carrier supplement alone (Horn et al., 1981; Andersen and Horn, 1987). In addition to improving grazing animal performance, both producer experience and research (Grigsby, 1984; Bagley and Feazel, 1989; Branine and Galyean, 1990) have indicated that monensin decreases the incidence and severity of frothy bloat associated with grazing winter wheat pasture; however, lasalocid, when provided at the same level, appears to be less effective than monensin in controlling frothy bloat associated with legumes (Bartley et al., 1983). Although ionophores reduce both feedlot and pasture bloat, no explanations for either mode of action responsible for the reduction in bloat, or for differences in efficacy between ionophores are apparent. The objective of this trial was to determine the effects of monensin and lasalocid on rumen characteristics, in vitro gas production, and bloat prevention in steers grazing winter wheat.

Materials and Methods

Twelve ruminally cannulated steers (528 ± 30 kg) were alloted by weight to three treatments, control, monensin, and lasalocid, with monensin steers receiving 300 mg monensin and lasalocid steers receiving 300 mg lasalocid daily. Control steers were not bolused. Steers grazed a common wheat pasture from January 30 to April 7, 1997 and were bolused at approximately 0830 beginning February 27 and continuing until completion of the trial.

Ruminal Fluid.

Ruminal fluid was collected once each week from all 12 steers for three consecutive weeks in an attempt to collect fluid from grazing animals at the time when wheat was at or near its greatest bloat potential. Steers were sampled prior to bolusing between 0830 and 0930 on March 13, 21, and 27, when they were actively grazing during their morning grazing bout (sunrise approximately 0630). Ruminal contents were systematically sampled from several areas of the rumen, strained through four layers of cheesecloth, and subsequently used to measure in vitro gas production. Sub-samples from each animal were used to determine ruminal pH and immediately acidified for ruminal volatile fatty acid (VFA) and ammonia analysis by adding 1 ml 20% H_2SO_4 (7.2 N) solution/50 ml of sample and refrigerated until ammonia analysis could be performed. Procedures used to determine ruminal ammonia concentrations were a modification of the magnesium oxide distillation method (AOAC, 1975). Ten milliliters of acidified ruminal fluid, 1 g of magnesium oxide, .5 g of powdered pumice stone, 1 ml of $CaCl_2$ (25% w/v in water) and five drops of caprylic alcohol were added to each macro-kjeldahl flask. Samples were prepared for VFA analysis by adding .05 g of meta-phosphoric acid to 5-ml aliquots of ruminal fluid for initial deproteinization and centrifuged at 20,000 x g for 10 min. Following centrifugation, approximately 2 ml of the supernatant fluid was saved and frozen for later analysis. Ruminal fluid samples were analyzed for VFA concentrations using a Perkin-Elmer Autosystem gas chromatograph with 2-ethylbutyric acid added as an internal standard. Strained, non-acidified ruminal fluid samples were frozen immediately after collection for subsequent mineral analysis. Thawed samples were initially spun at 1,000 x g to remove large feed particles, and the supernatant fluid was diluted 1:10 using a 2% HCl solution. Diluted samples were centrifuged at 10,000 x g for 15 minutes and decanted. The resulting pellet was discarded, with the supernatant fluid being analyzed for sodium, magnesium, potassium and calcium concentrations by atomic absorption spectrophotometry.

In vitro gas production was measured during each collection period using ruminal fluid collected from each steer. Rate as well as total gas production was measured during an 8 h period using an in vitro procedure with duplicate samples prepared for each steer. Twenty milliliters of ruminal fluid was incubated with .5 g of wheat forage in 25-ml volumetric flasks placed in a 39 C water bath. Flasks were sealed with stoppers equipped with rubber tubing that was connected to inverted burets filled with colored water. Gases produced during fermentation traveled through the tubing and into the water-filled burets. Gas production was monitored hourly for 8 h by measuring fluid displaced by gas.

Bloat Scores.

From March 15 through March 28, steers were monitored for bloat each morning at approximately 0900. Steers were evaluated in the pasture during their initial grazing bout and assigned a bloat score prior to bolusing. The scoring system, similar to that used by Branine and Galyean (1990) and Grigsby (1984), was intended to characterize the incidence and severity of bloat across the three treatments. Bloat scores were as follows:

0 = Normal, no visible signs of bloat.

1 = Slight distention of left side of animal.

2 = Marked distention of left side of animal. Rumen distended upward toward top of back. Animal has asymmetrical (egg-shape) look when walking away from observer.

3 = Severe distention. Distension is above top of back and visible from right side of animal.

Mean bloat score was calculated for each steer by averaging daily bloat scores across the 14-d observation period. Incidence of bloat was calculated for each steer as the total days in which bloat score was greater than zero.

Statistical Analysis

Ruminal fluid characteristics and in vitro gas production from all three periods were analyzed using the GLM procedure of SAS (1990) as a repeated measures design with treatment, steer, period, and treatment x period included in the model. Steer within treatment was used as the error term to test ionophore effects. Period measurements were separated by least significant differences when a significant treatment effect was detected. Treatment sums of squares were separated using orthogonal contrasts comparing control steers vs those receiving an ionophore (control vs ionophore), and the relative effectiveness of the two ionophores (monensin vs lasalocid).

Data relative to the incidence and severity of bloat were analyzed using the GLM procedure of SAS (1990) as a completely randomized design with animal as the experimental unit. Control vs ionophore and monensin vs lasalocid contrasts also were used to separate treatment sums of squares.

In order to identify relationships between the occurrence of bloat and ruminal fluid characteristics as well as in vitro gas production, data collected during periods two and three were re-analyzed using the observed bloat score for each steer determined prior to collection, and collection period (March 21 and March 27) as independent variables, regardless of ionophore treatment. Across both collection dates, only one steer was observed with a bloat score of two; no steers were observed with a bloat score greater than two. Therefore all steers were designated as bloated (bloat score of 1 or 2) or normal (no signs of bloat, bloat score 0) based on the presence of bloat. Corresponding ruminal fluid data were analyzed as a repeated measures design with bloat designation, steer, period, and bloat designation x period included in the model. Steer within each bloat designation was used as the error term to test bloat effects. Bloat designation measurements were separated by least significant differences when a significant treatment effect was observed.

Results and Discussion

No ionophore treatment x period interactions were detected ($P > .20$) for any ruminal fluid or in vitro gas production measurements, regardless of model used. Consequently, results are presented by main effects of treatment and collection date.

Effect of Collection Date on Rumen Fluid Characteristics.

Occurrence of bloat in steers was not closely observed during the first collection date; however, steers were closely monitored beginning March 15 as the incidence of bloat began to increase. Ruminal pH was lower ($P < .05$; Table 1) on March 21 compared to March 13 and 27. There was a similar increase ($P < .05$) in ruminal ammonia and total VFA concentrations during the same wk. Molar proportions of acetate were highest ($P < .05$) on March 13, resulting in a higher acetate:propionate ratio during the first collection period. Molar proportions of butyrate were lower ($P < .05$) on the March 13 collection date. In vitro gas production (total amount and rate) was also lower ($P < .05$) on March 21. The peak in VFA concentrations during March 21, as well as the decrease in acetate and increase in butyrate during March 21 and 27 may reflect differences in the size or degradability of the soluble fraction of wheat forage during the 3 wk period. Ruminal fluid Na concentrations were unchanged ($P > .05$) during the three wk collection period; however, K, Ca, and Mg concentrations were greater ($P < .05$) on March 21 and 27, compared with March 13. Stewart et al. (1981) and Turner (1981) observed that increases in forage potassium concentrations coincided with an increased bloat incidence and tetany susceptibility in winter wheat pastures. Similarly, Hall et al. (1988) and Majak and Hall (1990) report that in trials conducted with cattle fed fresh alfalfa, low ruminal concentrations of Na and high ruminal concentrations of K were associated with increased susceptibility to bloat. This increase in bloat was attributed to relative cation concentrations in the rumen, as cations can potentially bind to negatively-charged protein colloids in the rumen and thereby increase the formation and stability of ruminal foams. Ruminal Ca and Mg concentrations, as well as K:Na ratio, also are believed to affect occurrence of bloat, as cations with heavier atomic weights and greater valences have a greater ability to coagulate soil colloids (Vershinin et al., 1966).

Effect of Ionophore on Rumen Fluid Characteristics.

Control vs Ionophore. Ruminal pH was not affected by presence of an ionophore ($P = .33$; Table 2). Ruminal ammonia, total VFA, acetate and propionate concentrations also were unaffected ($P \geq .20$). Butyrate concentrations were decreased ($P = .04$) by the addition of an ionophore. Additionally, the acetate/propionate ratio was not altered ($P = .32$) by the addition of ionophore. While ionophore-treated and control steers had similar acetate, propionate, and acetate/propionate ratio responses, the control vs ionophore comparison may have masked differences in ruminal VFA concentrations between lasalocid and monensin, as discussed in the following section. Davenport et al. (1989) reported that the addition of 100 mg monensin/day administered via a ruminal delivery device did not alter ruminal pH and ammonia concentrations of steers grazing winter wheat. Andersen and Horn (1987) found that feeding 100 or 200 mg lasalocid$\cdot$steer$^{-1}\cdot$d^{-1} to heifers grazing winter wheat increased ruminal ammonia levels in year 1; however, no differences were detected in year 2. Monensin has been shown to decrease ruminal NH_3 concentrations (Horn et al., 1981; Poos et al., 1979) presumably due to inhibiting ruminal deamination and proteolysis of dietary protein, as suggested by Van Nevel and Demeyer, (1977). Lack of consistency in response may be related to the high ruminal ammonia concentrations associated with cattle grazing winter wheat (Horn et al., 1981; Andersen and Horn, 1987).

Calculated in vivo methane production per unit of glucose fermented (Owens and Goetsch, 1988) was similar for control steers and those receiving an ionophore; however, total gas production calculated from relative VFA concentrations of both ionophore treatments was lower ($P = .04$) than for control steers. This may be due to the large increase in propionate and decreased methane associated with steers receiving monensin.

Steers receiving ionophores tended to have lower ruminal fluid Na concentrations ($P = .08$), and higher K and Mg concentrations ($P \leq .08$) than control steers. Calcium concentrations were not affected ($P = .42$) by the addition of an ionophore. Russell (1987) reported that the addition of monensin to Streptococcus bovis cultures decreased intracellular K and increased intracellular Na. If this hypothesis is true, then the above mechanism would also create a related extracellular increase in K and decrease in Na concentrations. Because standard preparation of ruminal fluid for mineral analysis requires centrifugation to remove ruminal microbes, analyzed ruminal fluid is in essence, extracellular fluid, so our results would support the mechanism proposed by Russell (1987). However, our results disagree with Starnes et al. (1984) who measured ruminal mineral concentrations in steers offered a high concentrate diet containing no ionophore, 33 ppm monensin, or 33 ppm lasalocid. They found that steers fed either ionophore had lower ruminal concentrations of magnesium, calcium and potassium, with no differences in sodium concentrations. Possible reasons for this discrepancy include differences in mineral composition of basal diet, as well as potential differences in methods used to determine ruminal mineral concentrations. Steers receiving ionophores also tended ($P \leq .08$) to have higher potassium absorption ratios (PAR) and lower sodium absorption ratios (SAR). These ratios express the balance of monovalent and divalent ions in the rumen. Both ratios were used previously by Hall et al. (1988), who observed that bloated cattle had higher PAR and lower SAR value prior to occurrence of bloat. Relative ion concentrations are of interest because of their suggested influence on bloat susceptibility, as addressed by Hall et al. (1988) and Majak and Hall (1990). These results indicate that while ionophores may be effective in reducing bloat, the decreased sodium and increased magnesium and potassium concentrations caused by the addition of ionophores may be conducive to bloat based on the relative coagulating strengths reported by Vershinin (1966). This would suggest that the ability of ionophores to decrease incidence and severity of bloat is not related to their effect on relative mineral concentrations in ruminal fluid.

In vitro gas production/g of forage was similar ($P = .67$) for ruminal fluid from control steers and the average of both ionophore treatments, but differences existed between ionophores. Rate of gas production also was similar ($P = .61$) between control steers and those receiving ionophores. Again, relative differences ($P < .01$) in gas production between monensin and lasalocid treatments may have compromised the ability of the control vs ionophore contrast to detect treatment differences.

<u>Monensin</u> <u>vs</u> <u>Lasalocid</u>. Within the steers receiving ionophores, ionophore type did not affect pH, ruminal ammonia or total VFA concentrations ($P \geq .37$). However, steers receiving lasalocid tended ($P = .09$) to have a higher molar proportion of acetate compared with steers receiving monensin. Molar proportions of propionate were greater

($P < .01$) for steers receiving monensin, whereas butyrate proportions were higher ($P < .01$) for lasalocid steers. Higher acetate and lower propionate concentrations resulted in higher ($P < .01$) acetate:propionate ratios in steers receiving lasalocid. In previous wheat pasture grazing trials, monensin has either: 1)caused a slight increase in molar proportions of propionate when supplied at 100 mg/d via ruminal bolus (Davenport et al., 1989), 2) had little influence on molar proportions of acetate and propionate when offered in a supplement at 170 mg/d (Branine and Galyean, 1990), or 3) dramatically increased propionate and decreased acetate:propionate ratios when provided at 200 mg/d (Horn et al., 1981). Results from these trials suggest that the effect of monensin on relative proportions of VFAs in cattle grazing wheat pasture may be dose-dependent. In contrast, lasalocid, offered at 100 and 200 mg/d, did not affect acetate, propionate, or acetate:propionate ratios (Andersen and Horn, 1987) suggesting that lasalocid has less effect on ruminal VFA metabolism in steers grazing winter wheat. Relative changes in acetate and propionate also resulted in decreased ($P < .01$) CH_4 and total gas production based on rumen fermentation balance calculations for steers receiving monensin vs lasalocid. Horn et al. (1981) also reported that providing monensin at 200 mg/d decreased calculated methane and total gas production in steers grazing winter wheat. Thornton and Owens (1981) measured in vivo methane production by respiration calorimetry, observing a decrease in methane production when steers received 200 mg monensin$\bullet$steer$^{-1}\bullet$d^{-1} compared with steers receiving just the basal diet. In comparing previously conducted trials involving wheat pasture and the use of ionophores (Horn et al., 1981; Andersen and Horn, 1987; Davenport et al., 1989; Branine and Galyean, 1990) with the results from this experiment, monensin appears to consistently decrease acetate:propionate ratios and calculated total gas production, with the size of the reduction appearing to be dose-dependant, whereas lasalocid produces less consistent effects on ruminal fermentation and calculated total gas production.

Ruminal fluid mineral concentrations (Na, K, Ca, and Mg) were similar ($P \geq .24$) for steers receiving lasalocid and monensin, reflecting the similarity of the diet, as well as similar relative mineral affinities for both polyether ionophores.

In vitro gas production per gram of forage was greater ($P < .01$) in ruminal fluid from steers receiving monensin, although there were no differences in rate of gas production ($P = .16$). Kone and Galyean (1990) reported that in vitro gas production was increased when various ratios of monensin and lasalocid were added to in vitro culture tubes. Similarly, Bartley et al., (1979) observed that in vitro gas production was increased when monensin and lasalocid were added to culture tubes at 22, 44, 88, and 176 ppm. Although in vitro gas production was greater for steers receiving monensin, in vivo results (Thornton and Owens, 1981; Horn et al., 1981), as well as calculated in vivo gas production from this trial indicate that methane and total gas production was decreased by ionophores. Therefore, rate of gas production as determined by the in vitro procedure used in this study may not be a good indicator of in vivo ruminal gas production and(or) the incidence of bloat.

Incidence and Severity of Bloat.

From March 15 through March 28, steers were monitored daily for signs of bloat, and each were assigned a bloat score based on the severity of bloat (Table 3). Control steers tended ($P = .10$; Table 4) to have more steer days of bloat and greater mean bloat scores compared with steers that received an ionophore. Monensin decreased ($P \leq .05$)

both the incidence (mean days of bloat/steer) and the severity (mean bloat score/steer) of bloat as compared with lasalocid. Both Grigsby (1984) and Branine and Galyean (1990) reported a lower occurrence of bloat, as well as decreased bloat severity by the addition of monensin (160 and 170 mg/d, respectively) to supplements fed to steers grazing winter wheat pastures. Similarly, Bagley and Feasel (1989) observed a lower incidence of bloat in steers receiving monensin ruminal boluses (100 mg/d) compared with non-bolused steers grazing ryegrass and clover pastures (33 and 4%, respectively, for non-bolused and bolused steers). Finally, Bartley et al., (1983) evaluated the efficacy of monensin and lasalocid at controlling feedlot (grain) and legume bloat, finding that monensin was more effective than lasalocid in reducing average bloat score of steers grazing lush, pre-bloom alfalfa. These results suggest that monensin is more efficacious than lasalocid in decreasing the incidence and severity of bloat in cattle grazing winter wheat.

<u>Relationship Between Bloat Score and Ruminal Fuid Parameters</u>.

In an attempt to measure differences in ruminal fluid characteristics, as well as in vitro gas production, collected data were compared based on the presence or absence of bloat as observed for each steer immediately prior to ruminal fluid collection, regardless of treatment (Table 5). Ruminal pH, NH_3, total VFA concentrations, and molar proportions of acetate were similar ($P > .05$; Table 6) for normal and bloated steers. Molar proportions of propionate were lower ($P < .05$) for steers with bloat. Calculated CH_4 and total gas production both were greater ($P < .05$) in bloated steers, suggesting that ruminal gas production may be an important factor affecting an animals susceptibility to bloat. No differences ($P > .05$) were observed in mineral concentrations or in vitro gas production between normal and bloated steers.

Implications

Cattle grazing winter wheat and receiving monensin had higher molar proportions of propionate and lower acetate:propionate ratios compared with steers receiving lasalocid. This shift in ruminal fermentation patterns resulted in lower calculated CH_4 and total gas production for steers receiving monensin. In addition, monensin was more effective than lasalocid at reducing both the incidence and severity of bloat. These results suggest that ionophores may reduce bloat in part by reducing ruminal gas production.

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Table 1. Effect of collection date on ruminal fluid parameters.

Item	March 13[a]	March 21	March 27	SE[b]
No. of steers	12	12	12	
No. of steers bloating	Not Meas.	6	5	
	Ruminal fluid analysis			
pH	5.74[g]	5.56[f]	5.66[g]	.033
NH3, mg/100 ml	48.11[f]	57.66[g]	45.25[f]	1.543
Total VFA's, mmol/l	118.57[f]	157.32[g]	155.61[g]	1.881
Acetate, mol/100 mol	62.13[g]	59.39[f]	60.22[f]	.517
Propionate, mol/100 mol	19.50	20.02	20.17	.363
Butyrate, mol/100 mol	12.10[f]	13.75[g]	13.58[g]	.273
A/P ratio	3.24[g]	2.99[f]	3.02[f]	.073
CH_4, moles[c]	32.24	31.57	31.86	.264
$CH_4 + CO_2$, moles[c]	86.33	86.90	87.38	.365
Sodium, Meq/L	88.22	82.20	84.70	1.844
Potassium, Meq/L	55.89[f]	65.16[g]	66.12[g]	1.600
Calcium, Meq/L	4.87[f]	6.98[g]	6.57[g]	.266
Magnesium, Meq/L	8.44[f]	10.59[g]	10.62[g]	.289
PAR[d]	21.67	21.96	22.53	.459
SAR[e]	34.43	27.99	29.21	1.039
	In vitro gas production			
In vitro gas production, ml/g forage	52.04[g]	43.32[f]	55.18[g]	1.319
Linear slope of in vitro gas prod., ml gas/h	2.15[g]	1.48[f]	2.11[g]	.068

[a]Least squares means for each collection period.
[b]Standard error of least squares means.
[c]Calculated values based on relative molar proportions of acetate, propionate, and butyrate.
[d]Potassium absorption ratio, $[K] / (([Ca] + [Mg])/2)^{0.5}$.
[e]Sodium absorption ratio, $[Na] / (([Ca] + [Mg])/2)^{0.5}$.
[f,g]Means within a row with different superscripts differ ($P < .05$).

Table 2. Effect of ionophore on ruminal fluid parameters of steers grazing winter wheat.

Item	Control[a]	Monensin	Lasalocid	SE[b]	Control vs Ionophore[c]	Monensin vs Lasalocid
No. of cannulated steers	4	4	4			
	- Ruminal fluid analysis - - - - - - - - - - - - - - - - - - -					
PH	5.62	5.70	5.64	.037	.33	.37
NH_3, mg/100 ml	47.90	51.88	51.24	2.317	.23	.85
Total VFA's, mmol/l	141.37	144.33	145.81	3.100	.36	.74
Acetate, mol/100 mol	60.69	59.56	61.50	.731	.87	.09
Propionate, mol/100 mol	19.21	22.05	18.43	.614	.20	<.01
Butyrate, mol/100 mol	14.06	11.51	13.86	.456	.04	<.01
A/P ratio	3.18	2.73	3.35	.114	.32	<.01
CH_4, moles[d]	32.57	30.02	33.07	.517	.14	<.01
$CH_4 + CO_2$, moles[d]	88.81	82.58	89.21	.983	.04	<.01
Sodium, Meq/L	91.37	82.51	81.24	3.870	.08	.82
Potassium, Meq/L	56.25	64.79	66.14	3.756	.08	.80
Calcium, Meq/L	5.83	6.69	5.90	.449	.42	.24
Magnesium, Meq/L`	9.26	10.17	10.22	.353	.06	.94
PAR[e]	20.45	22.38	23.33	1.009	.08	.52
SAR[f]	33.57	28.93	29.14	1.729	.06	.93
	- In vitro gas production - - - - - - - - - - - - - - - - - - -					
In vitro gas production, ml/g forage	50.91	54.42	45.22	2.013	.67	.01
Rate of gas production (linear), ml gas/hr	1.95	1.99	1.80	.088	.61	.16

[a]Least squares means for each collection period.
[b]Standard error of least squares means.
[c]P-value associated with orthogonal contrasts.
[d]Calculated values based on relative molar proportions of acetate, propionate, and butyrate.
[e]Potassium absorption ratio, $[K] / (([Ca] + [Mg])/2)^{0.5}$
[f]Sodium absorption ratio, $[Na] / (([Ca] + [Mg])/2)^{0.5}$

Table 3. Distribution of bloat scores during the 14-d observation period[a,b].

	Control steers				Monensin steers				Lasalocid steers			
Date	1	2	3	4	5	6	7	8	9	10	11	12
Mar. 15	1	1	1	1	0	0	0	0	3	1	2	0
Mar. 16	2	2	0	0	1	0	0	0	2	0	2	0
Mar. 17	1	2	1	1	1	0	0	0	1	0	1	0
Mar. 18	1	1	0	1	1	0	0	0	1	1	0	0
Mar. 19	1	0	0	1	0	0	0	0	1	1	1	0
Mar. 20	1	1	0	1	0	0	0	0	1	2	2	0
Mar. 21	1	2	0	1	0	0	0	0	1	1	1	0
Mar. 22	1	2	0	1	0	0	0	0	1	1	0	0
Mar. 23		2	0	2	0	0	0	0	1	1	0	0
Mar. 24	1	1	0	1	0	0	0	0	1	1	0	0
Mar. 25	1	1	0	2	0	0	0	0	0	2	0	0
Mar. 26	1	1	0	1	0	0	0	0	2	2	1	1
Mar. 27	1	1	0	1	0	0	0	0	1	1	0	0
Mar. 28	1	0	0	1	0	0	0	0	1	1	0	0

[a]Steers were monitored daily between 0830 and 0900 for signs of bloat. Steers were actively grazing wheat, prior to handling.

[b]Bloat scoring system of: 0 = no visible signs of bloat
1 = slight distention of left side
2 = marked distension of left side
3 = left and right sides distended

Table 4. Effect of treatment on incidence and severity of bloat[a,b]

Item	Control[c]	Monensin	Lasalocid	SE[d]	Control vs ionophore[e]	Monensin vs Lasalocid
No. of steers	4	4	4			
No. of steers that bloated[f]	4	2	4			
Total steer d of bloat	40	4	33			
Mean d of bloat/steer	10.0	1.0	8.3	2.25	.08	.05
Mean bloat score/steer	.88	.07	.77	.207	.10	.04

[a]From March 15 to March 28, 14 d.

[b]Bloat scoring system of: 0 = no visible signs of bloat
1 = slight distention of left side
2 = marked distension of left side
3 = left and right sides distended

[c]Least squares means for each collection period.

[d]Standard error of least squares means.

[e]P-value associated with orthogonal contrasts.

[f]Steers given a bloat score greater than zero on one or more d.

Table 5. Distribution of bloat across treatment on two collection dates, March 21 and March 27.

Collection Date	Steers with bloat score of 0 (normal)			Total number of normal steers	Steers with bloat score > 0 (bloat)			Total number of bloated steers
	Con	Mon	Las		Con	Mon	Las	
March 21	1	4	1	6	3	0	3	6
March 27	1	4	2	7	3	0	2	5

Table 6. Comparison between bloat score and ruminal fluid parameters.

Item	Observed Bloat[a] Normal	Bloated	SE[b]
	---------- Ruminal fluid analysis ---------		
PH	5.64	5.55	.035
NH_3, mg/100 ml	50.94	52.67	1.874
Total VFA's, mmol/l	155.30	158.60	2.546
Acetate, mol/100 mol	59.31	60.51	.618
Propionate, mol/100 mol	21.09[f]	18.79[g]	.609
Butyrate, mol/100 mol	13.01	14.54	.623
A/P ratio	2.84[f]	3.23[g]	.113
CH_4, moles[c]	30.89[f]	32.83[g]	.525
CH_4+CO_2, moles[c]	85.33[f]	89.60[g]	1.242
Sodium, Meq/L	84.51	82.82	4.489
Potassium, Meq/L	64.26	67.37	4.333
Calcium, Meq/L	7.01	6.77	.509
Magnesium, Meq/L	10.44	10.82	.489
PAR[d]	21.72	22.73	1.113
SAR[e]	28.89	28.24	2.087
	--------- In vitro gas production ---------		
In vitro gas production, ml/g forage	50.19	48.01	2.436
Linear slope of in vitro gas prod., ml gas/h	1.83	1.78	.071

[a]Least squares means where bloat score of 0= normal and bloat score > 0=bloated appearance.
[b]Standard error of least squares means.
[c]Calculated methane production based on relative molar proportions of acetate, propionate and butyrate.
[d]Potassium absorption ratio, $[K] / (([Ca] + [Mg])/2)^{0.5}$
[e]Sodium absorption ratio, $[Na] / (([Ca] + [Mg])/2)^{0.5}$
[f,g]Means within a row with different superscripts differ ($P < .05$)

CHAPTER V

EVALUATION OF WHEAT VARIETIES FOR GRAZING AND GRAIN

S.I. Paisley, G.W. Horn, E.G. Krenzer, L.A. Redmon, D.S. Buchanan and C. Lunsford

ABSTRACT

Sixteen 7.3- to 9.7-ha clean-tilled winter wheat pastures were used to study the effects of wheat variety and stocking rate (SR) on cattle performance and grain yield of winter wheat (Triticum aestivum) pasture. Four hard red winter wheat varieties were each grazed at four stocking rates to characterize live weight gain of growing beef cattle and grain yield during the wheat pasture years of 1992-'93, '93-'94, '94-'95 and '96-'97. Wheat varieties used during the first two yrs were semidwarf varieties 'Karl', '2163', '2180' and 'AgSeCo 7853'; varieties used in yrs 3 and 4 included '2180', 'AgSeCo 7853', 'Longhorn' and 'Scout 66'. Fall-weaned steers (227 kg) grazed winter wheat continuously with SR ranging from .9 to 2.8 steers/ha with steers removed from pastures when first hollow stem was detected in ungrazed plants. Pasture means were analyzed using variety, SR (continuous variable), and variety x SR as sources of variation. Stocking rate appeared to have a greater effect than wheat variety on season-long steer weight gains. While weight gain/steer was unaffected ($P \geq .35$) by variety in three of the four years, increasing SR decreased ($P < .01$) gain/steer during all four years. Across all yrs, increasing SR decreased season-long steer gains by -18 to -58 kg. Although individual animal performance was reduced, increasing SR resulted in increased ($P < .01$) gain/hectare during three of the four years. An unusually wet winter depressed both gain/steer and gain/ha during yr 1. Although root rot affected grain yields during yr 3,

grain yield of semidwarf varieties in yrs 1, 2 and 4 was very sensitive to SR, decreasing ($P \leq .05$) as SR increased even though cattle were removed from pastures at first hollow stem. Overall, stocking rate had a larger influence on grazing animal performance and grain yield, with minimal effects related to wheat variety.

Key words: Winter Wheat, Variety, Stocking Rate, Grain Production

Introduction

In addition to producing a grain crop, a majority of winter wheat grown in the Southern Great Plains provides high quality forage for livestock grazing throughout the winter months. The Oklahoma Agricultural Statistics Service (OASS) estimates that approximately 57% of wheat planted in Oklahoma is grazed (Epplin, 1997). Despite the widespread use of winter wheat as a dual-purpose crop, wheat variety selection has traditionally been based primarily on grain yield, disease and insect resistance, lodging, test weight, and other grain-related production characteristics. Few research trials have evaluated winter wheat varieties based on both forage and grain production. There is evidence that forage production is important in maximizing net returns/acre in grazing and grain operations. Krenzer et al. (1996) reported that differences in forage production (determined by clipping plots) and grain yield of 12 varieties of winter wheat resulted in a $81.27 range in estimated net returns/acre. Net returns/acre were estimated for all varieties based on test plot grain production as well as estimated beef production using calculations based on forage clipping data. Forage production, as determined by mechanical clipping of plots, may not accurately reflect actual differences that occur in grazed winter wheat, where timing and severity of livestock grazing can affect subsequent forage and grain production. Research with ryegrass (*Lolium multiflorum*) and orchardgrass (*Dactylis glomerata*) pastures indicates that forage regrowth is proportional to leaf area remaining after defoliation (Milthorpe and Davidson, 1996; Smith, 1974, Booysen and Nelson, 1975). Additionally, season-long grazing of semidwarf varieties of winter wheat may result in reductions in grain yield despite the removal of cattle prior to jointing (Redmon et al., 1995). Timing and severity of grazing, as well as the individual variety's potential forage and grain production in response to grazing probably both play a role in determining net returns/acre in dual purpose production systems. The objective of these grazing studies was to determine the effect of variety and stocking rate on live weight gains of growing cattle and beef and grain production per acre where wheat is used as a dual-purpose crop.

Materials and Methods

Study site.

All wheat variety x stocking rate trials were conducted at a wheat pasture research facility approximately 56 km west of Stillwater Oklahoma, near Marshall. The 178-ha facility included sixteen 8.2 to 10.9-ha pastures planted to hard red winter wheat intended for livestock grazing as well as grain production. Four hard red winter wheat varieties were chosen for each year of the study. In yrs 1 and 2, four semidwarf varieties (2180, 2163, AgSeCo 7853, and Karl) were chosen to represent popular wheat varieties grown by producers in Oklahoma. In yrs 3 and 4, 2163 and Karl were replaced with Longhorn and Scout 66. All varieties were selected for tolerance to soilborne mosaic virus and were rated better than average for leaf rust (Puccinia spp.) resistance at the time of the study. Rationale for selecting each variety, as well as the years each variety was used, is included in Table 1.

Soil samples were collected for nutrient analysis in late July of each yr. Both surface (0-20cm) and subsoil (20 – 61cm) were collected to accurately estimate N carry-over. Anhydrous ammonia was applied pre-plant to provide enough N for a yield goal of 3370 kg of forage and 3360 kg of grain/ha. In addition, diammonium phosphate (18-46-0) was applied in the seed furrow at planting to meet the phosphorous requirements and to provide a starter fertilizer. Initial soil pH ranged from 4.7 to 4.9 prior to planting in yr 1, and two tons of ECCE lime were applied during the summer of 1992. By the summer of 1994, the soil pH appeared to have stabilized at 5.7. Wheat was seeded in early September of each yr with a targeted seeding rate of 134 kg/ha for all varieties. Grain yield was measured each yr by cutting two swaths the entire length of each pasture with a Gleaner A combine equipped with an 2.44-m header. Cattle grazed wheat pastures continuously from early November until each variety reached the first hollow stem stage of maturity. Grazing initiation and termination dates and stocking rates are listed in Table 2. First hollow stem stage was defined as the growth stage at which hollow stem can first be identified above the crown in the larger wheat shoots of ungrazed wheat and occurs prior to the growing point (head) reaching the soil surface. First hollow stem is the earliest portion of the jointing stage, analogous to growth stage 30 as defined by Tottman and Broad, (1987).

Stocking rates

During yrs 1 and 2, pastures were grazed using four set stocking rates ranging from 1.04 to 2.05 steers/ha (Table 2). The range in stocking rates was gradually increased each year in an attempt to characterize forage and grain production responses across a wider range of stocking rates. During the last two years of the study, stocking rates were established using a variable stocking rate grazing system based on available forage to ensure similar grazing pressures for all wheat varieties. Available forage was determined from forage mass estimates determined by systematically clipping four .186 m^2 quadrats to ground level in each pasture. The lightest stocking rate was established at approximately .9 to 1.1 steers/ha, and stocking rates were adjusted slightly for each variety to create similar herbage allowance (kg forage/ 100 kg BW) for all varieties based on initial clipping data. Heavier stocking rates were assigned, based on individual pasture clipping data, to provide 80, 60, and 40% of the herbage allowance as compared with the lightest stocking rate. The range of stocking rates determined using this system produced ranges was similar to those used in yrs. 1 and 2. Forage mass was determined immediately prior to each interim weight, and stocking rates were adjusted following weighing to maintain similar ranges of herbage allowance across all varieties.

Nutritive value

Prior to each intermediate and final weight, pastures were hand-clipped to determine forage mass/ha. In addition to forage mass, three diet quality samples were also collected from each pasture, attempting to remove only the top 1/3 of leaf area. Samples were subsequently dried in a 55°C oven to constant weight, and ground to pass a 2 mm screen using a Wiley mill. Forage samples for each collection period were analyzed for percent ash, crude protein (years 1 and 2) and organic matter disappearance (OMD) using a 48 hour in-vitro procedure (Ellis, personal communication). To determine OMD, .5 g of forage was incubated in buffered ruminal fluid for 48 h.

Following incubation, samples were immediately frozen until further analysis could be performed. An NDF extraction procedure was performed on the thawed sample. Residue remaining after filtering was then ashed to determine ash content of the residue. In vitro disappearance values were then calculated using the organic matter content of the original sample, and the remaining organic matter of the NDF residue. In vitro organic matter disappearance was then converted to in vivo values by regressing in vitro organic matter disappearance values of known standards on their in vivo organic matter digestibility. In vivo digestible organic matter (DOM) values were calculated from in vivo OMD by multiplying by the organic matter content of the initial samples.

Cattle

Fall-weaned steer calves were used in each year of the study. Calves were initially vaccinated within 24 h of arrival with 1) modified live virus (MLV) strains of IBR, BVD and BRSV plus a Leptospira pomona bacterin, 2) an intranasal IBR/PI3 vaccine and 3) a Pastuerella haemolytica bacterin-toxoid "One-shot". During the receiving program, calves had ad libitum access to bermudagrass (*Cynodon dactylon*) hay and were hand-fed .91 kg/d of a high-protein, soybean meal based supplement that contained added vitamin E, selemium and Deccox. Nine days after the initial vaccination the calves were revaccinated with: 1) MLV strains of IBR, PI3 and BRSV 2) a 5-way clostridial bacterin-toxoid and 3) "One-Shot" and were given an injection of ivermectin. The steers were implanted with Synovex-S immediately prior to placement on wheat pasture. During the wheat pasture grazing period, calves had free-choice access to a high-calcium (15-17% Ca) commercial mineral mixture ("Wheat Pasture Pro Mineral", Farmland Industries, Inc.), but did not receive any other supplemental feed other than limited amounts of alfalfa (*Medicago sativa*) hay during periods of snow cover.

In yr 1, 204 steer calves of predominantly Angus or Angus X Hereford breeds were used in the study. The calves originated near Harlem and Chinook, Montana. During yr 2, 196 British X Continental or Beefmaster Crossbred steers originating near Elk Mountain, Wyoming were used. Two hundred and ten crossbred calves originating from a single ranch near Paris, Texas were used in yr 3, and were predominantly of two types: 1) Simmental (Fleckvieh) sired calves from F1 Hereford X Brahman dams, and 2) Simmental, Limousin or Brangus-sired calves from Brangus or black white-faced dams. Two hundred three crossbred calves from Brangus and Braford cows were used in yr 4, with calves sired by Limousine, Brangus, Beefmaster and Hereford bulls.

Calves were weighed prior to initiation of grazing, and steers were allotted to the various variety and stocking rate treatments to result in similar initial weights for all pastures. Interim weights were taken 1 to 2 times during the grazing period, and final steer weights were recorded at grazing termination. Animal performance (gain/steer and gain/ha) were determined during yrs 3 and 4 according to performance of "tester steers" assigned to each pasture. Proper stocking rates were maintained by adding and subtracting "grazer" steers, which not included in animal performance data.

Statistical Analysis

Animal performance, gain/acre, grain yield and nutritive value data were analyzed using ordinary least squares procedures of SAS (1990). Sources of variation included variety, stocking rate (SR), which was included as a continuous variable, and the variety x SR interaction. When the variety x SR interaction was non-significant (P > .20) a reduced model was used, which included variety and SR (continuous variable), omitting the variety x SR term. The reduced model was also used to generate a single regression coefficient for SR. For all four years of the study, least squares means for wheat variety were generated using the appropriate model. Only linear effects of increasing stocking rate were tested, because including additional variables in the full model to test for non-linear effects of SR would greatly reduce the error degrees of freedom, decreasing the ability to detect treatment differences.

Animal performance, gain/acre and grain yield data were also analyzed using a model containing variety and SR within variety (continuous variable) as sources of variation. This model tested the effect of stocking rate within each variety, producing unbiased estimates of the linear slope of stocking rate for each variety, similar to dummy variable analysis. Additional contrast statements were developed to determine intercept values for each variety, as well as compare slopes and intercepts within varieties when there was a significant variety x SR interaction.

Data from variety 2163 were omitted from yr 2 because we did not achieve as heavy a grazing pressure, as measured by steer grazing days per metric ton of forage. Also during yr 2, data associated with one pasture planted to Karl was also removed because steer performance increased with increased stocking rate, suggesting that we did not achieve adequate grazing pressure compared with remaining varieties. During yr 4, grain yield data for variety 2180 was omitted because a late freeze severely reduced grain yield on the early-maturing variety, while grain yields for the remaining varieties were unaffected by the freeze.

Results and Discussion

Steer gains

Steer weight gains were affected by wheat variety ($P < .10$) during yrs 1 and 2; however, gain/steer was similar ($P > .19$) for all four varieties during yrs 3 and 4 (Table 3). Differences in steer performance due to wheat variety during years 1 and 2 may be partially related to the set stocking rate system used during the first two years of the study. Potential differences in forage production, while not measured directly in this study, may have resulted in differences in forage mass across varieties, which may have affected animal performance. Switching to a variable stocking rate system in yrs 3 and 4 based on forage available for grazing resulted in similar ($P > .19$) animal performance during the final two years of the study.

Increasing stocking rates resulted in a decrease ($P < .01$) in gain/steer during the four-year experiment. Gain/steer responses to increasing stocking rate for year 4 are provided (Figure 1) as an example of steer weight gain response to increasing stocking rate. A variety by stocking rate interaction ($P < .05$) in yr 2 suggested that the varieties may respond differently to increasing stocking rate. Weight gains at the lowest stocking rate were greater for steers grazing 2180 as compared with Karl and AgSeCo 7853, but gain/steer decreased more rapidly for 2180 and AgSeCo 7853 as stocking rate increased. Regression coefficients by variety were -4.5, –31.8, and -15.5, respectively, for Karl, 2810, and AsSeCo 7853. The lack of response by Karl, as indicated by the smallest regression coefficient, is possibly related to reduced grazing pressure as compared with 2180 and AgSeCo 7853 despite having the same range in stocking rates. Although the weight gain response for Karl in yr 2 was relatively flat, steer performance in general did not appear to level off even at the lightest stocking rates. Stocking rate models proposed by Petersen et al. (1965), Conway (1974) and Hart (1978) indicate that animal gains plateau at stocking rates below the critical stocking rate. Lack of a plateau for gain/steer in this experiment may indicate that stocking rates were still greater than the critical stocking rate. Additionally, Hart (1978) suggested that few grazing experiments contain sufficient data at very light stocking rates to clearly detect critical stocking rates. As stocking rate increased, gain/steer appeared to decrease linearly across the tested range of stocking rates; however, lack of experimental units would not allow us to accurately test for higher degree polynomial relationships. While the shape of the animal response curve at greater than critical stocking rates is highly debated, a linear decrease in steer performance agrees with Cowlishaw (1969), who reported that gain/steer responded linearly to increasing stocking rates based on an extensive review of grazing trials on high quality irrigated pastures as well as native range. In general, increasing stocking rate had a greater effect on steer weight gains than wheat variety. Stocking rate decreased ($P < .01$) gain/steer in all four years of the study, whereas variety only influenced ($P < .10$) steer gains during yrs 1 and 2. In addition, the relationship between animal performance and stocking rate appeared to be linear across the range of stocking rates tested.

Gain per Hectare

Across the four years of the study, wheat variety did not influence ($P \geq .19$) steer gain per acre (Table 4); however, gain/ha was affected ($P \leq .05$) by stocking rate in all four years, with steer gain/ha increasing as stocking rate increased during three of the four years. Steer weight gain/ha for year 4 is provided, illustrating the increase in gain/ha as stocking rate increased (Figure 2). Dramatic decreases in steer gains as stocking rate increased in yr 1 resulted in decreased gain/ha. This decrease in gain/ha with increasing stocking rate may be attributed to reduced overall animal performance related to the very wet winter during yr 1. Although Hart (1978) suggested that gain/ha responded quadratically as stocking rate increased, gain/ha appeared to respond linearly as stocking rate increased during all four years. The increased gain/ha associated with each increase in stocking rate during the remaining three years of the grazing study suggest that stocking rates may still have been too light to produce a characteristic plateau and(or) decline in gain/acre at the heaviest stocking rates. Hull et al. (1961) reported results from grazing trials where steers grazed orchardgrass/clover pastures at five stocking rates ranging from .55 to 1.89 steers/ha, indicating that gain/hectare increased linearly with stocking rate up to 1.6 steers/ha. While our heaviest stocking rate was 2.8 steers/ha, the average heavy stocking rate during the four-year trial averaged 2.2 steers/ha. Although these stocking rates exceed the range reported by Hull (1961), pastures planted to winter wheat may be able to support very high gains/acre. Wheat forage in the vegetative state is highly digestible, with dry matter digestibilities estimated at 75 to 76% (Zorrilla-Rios et al., 1985; Vogel et al., 1987) and crude protein levels ranging from 20 to 30% (Horn, 1984), The high nutritive value of wheat forage suggests that maximum gain/acre may be achieved at higher stocking rates than those previously tested.

Grain yield

Grain yield was similar for the four varieties tested during yrs 1 and 2 ($P \geq .18$; Table 5), although a variety x SR interaction ($P = .14$) occurred during year 2. Grain yield was affected by wheat variety ($P \leq .01$) during years 3 and 4. The greater effect of variety during years 3 and 4 may be due partially to the switch from set stocking to variable stocking rates, as well as replacing varieties Karl and 2163 with Longhorn and Scout 66. The differences in grain yield response occurring during yr 2 may be related to differences in relative grazing pressure between varieties. At the lightest stocking rate, 2180 had the highest grain yield, but its yield decreased more rapidly as stocking rate increased, as shown by SR regression coefficients of –717, -256, and –221, respectively, for 2180, AgSeC0 7853, and Karl varieties. The more rapid decline in grain production coincides with the rapid decrease in steer gains associated with 2180. Lower gains/steer at the highest stocking rates suggests that 2180 was grazed more severely, which may partially explain the associated decreased grain yields. Pumphrey (1970) suggested that any grazing of semidwarf wheat during the spring would result in decreased grain yield. Additionally, Winter and Musick (1991) reported that semidwarf wheat grain yield decreased linearly as leaf area index (as determined by a LI-COR leaf area meter) decreased at anthesis. More severe grazing would mean less leaf surface area at grazing termination, which may contribute to decreased grain yields. Increasing stocking rate resulted in decreased ($P < .05$) grain yields in all years excluding yr 3, which supports the proposed theory. Grain yield data from year 4 (Figure 3) illustrates the negative relationship between grain production and stocking rate (steers/ha). In 1994-95, an unusually mild winter resulted in severe root rot (*Bipolaris sorokiniana* and(or) *Fusarium spp.*) that depressed grain yields across all varieties. While all yields were reduced compared with previous years, Longhorn and Scout 66 experienced a more severe grain yield reduction than 2180 and AgSeCo 7853. Significant variety effects in years 3 and 4 indicate biological and economic differences in grain yield between the varieties tested.

Large variations in grain yield responses, as well as limited observations/variety may have contributed to the inability to detect variety differences in years 1 and 2. Despite removing cattle prior to first hollow stem, stocking rate still had a large effect on grain yield, with increasing stocking rates reducing grain yield in all years except year 3.

Nutritive value

In vitro organic matter digestibilities were similar ($P \geq .25$) at the initiation of grazing during all three years. Differences in forage digestibility were detected between varieties on the December 14 sampling date in year 1, however, a variety x SR interaction ($P = .07$) was also evident, indicating that forage digestibilities for each variety behaved differently as SR increased. Except for initial samples taken each year, stocking rate affected ($P < .01$) forage digestibity during all three years of the study. The effect of SR also appeared to increase as the grazing season progressed during each year. Although SR influenced ($P < .01$) forage digestibility, There were no variety effects ($P > 10$) during year 2; however, a variety X SR interaction ($P = .05$) occurred at grazing termination. Variety x SR interactions ($P < .01$) occurred on all but the initial clipping date during year 3. Although differences were detected, there were no consistent variety or SR trends. Low standard errors may have contributed to the diffrences in variety, SR, and variety x SR.

While differences were detected for in vivo digestible organic matter values, influences of variety and stocking rate were difficult to interpret, and differences in digestibility were small. No consistent trends were detected in either variety or SR.

Differences in digestibility do not appear to be large enough to affect performance of stocker cattle.

Implications

While differences in grain and forage production exist between wheat varieties, we were unable to detect consistent variety effects on animal gains and(or) grain yield. Stocking rate had a greater and more consistent influence on gain/steer, gain/acre, and grain production. It appears that determining the proper stocking rate may have a greater effect on maximizing net returns to grazing and grain operations than wheat variety.

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Table 1. Winter wheat varieties used during variety x stocking rate grazing trials.

Variety	Mature size Classification	Rationale for being included in trial	Year planted 1992	1993	1994	1996
Karl	Semidwarf	Popular Oklahoma variety				
		Excellent grain production and test weight.	X	X		
		Average forage production				
2163	Semidwarf	Low pH tolerant				
		Excellent grain production	X	X		
		Excellent forage production				
2180	Semidwarf	Very early maturing variety				
		Good grain production	X	X	X	X
		Excellent forage production				
7853	Semidwarf	Excellent grain production				
		Poor forage production	X	X	X	X
Longhorn	Semidwarf	Popular variety in Oklahoma			X	X
Scout 66	Tall	Older, tall variety				
		Longer coleoptile length allows earlier planting in the fall			X	X

Table 2. Grazing dates and stocking rates used in variety x stocking rate grazing trials.

	Starting Date	Ending Date	Days Grazed	Season-Long Stocking Rate, steers/ha			
1992-1993							
Karl	November 18, 1992	March 10, 1993	112	1.24	1.51	1.78	2.05
2163	“	“	“	“	“	“	“
2180	“	“	“	“	“	“	“
AgSeCo 7853	“	“	“	“	“	“	“
1993-1994							
Karl	November 2, 1993	March 15, 1994	133	1.04	1.51	1.78	2.05
2163	“	“	“	“	“	“	“
2180	“	“	“	“	“	“	“
AgSeCo 7853	“	“	“	“	“	“	“
1994-1995							
2180	November 1, 1994	February 25, 1995	116	.96	1.41	1.88	2.25
AgSeCo 7853	“	March 6, 1995	125	.89	1.09	1.61	2.30
Longhorn	“	March 6, 1995	125	.99	1.46	1.78	2.82
Scout 66	“	March 15, 1995	134	1.06	1.31	1.93	2.27
1996-1997							
2180	October 25, 1996	February 24, 1997	122	1.14	1.09	1.72	2.70
AgSeCo 7853	“	March 8, 1997	134	.93	1.03	1.60	2.24
Longhorn	“	February 24, 1997	122	1.14	1.49	1.59	2.31
Scout 66	“	March 8, 1997	134	.97	1.31	1.54	1.92

Table 3. Effect of wheat variety and stocking rate on weight gain of steers (kg).

Year	1 (92/93)	2 (93/94)	3 (94/95)	4 (96/97)
Variety	†	*	.19	.82
Stocking Rate (SR)	***	**	***	**
Variety * SR	.22	*	.85	.26
Y-intercept for SR, kg	186.1	164.8	185.0	150.0
Regression Coefficient for SR[a]	-70.7	-17.6[b]	-23.5	-17.5
Range of SR, steers/ha	.82	1.01	1.48	1.48
Difference over range of SR, kg/steer	-58	-18	-35	-26
---------------------- LS Means, kg/steer --------------------				
Karl	69.9	137.5	--	--
2163	76.4	--	--	--
2180	82.4	141.9	140.6	125.1
AgSeCo 7853	57.2	138.4	129.3	126.0
Longhorn	--	--	142.4	127.5
Scout 66	--	--	145.9	121.9
SE	6.53	1.99	5.36	4.26

†= $P < .10$; * = $P < .05$; ** = $P < .01$; *** = $P < .001$.

[a]Change in grain yield (kg/ha) for each unit change in SR (steer/ha)

[b]Regression coefficients were -4.5, -31.8, and -15.5 for Karl, 2180 and AgSeCo 7853, respectively.

Table 4. Effect of wheat variety and stocking rate on steer gain/ha (kg).

Year	1 (92/93)	2 (93/94)	3 (94/95)	4 (96/97)
Variety	.19	.93	.29	.57
Stocking Rate (SR)	*	***	***	***
Variety * SR	.34	.22	.90	.68
Y-intercept for SR, kg	182.4	36.3	88.3	44.2
Regression Coefficient for SR[a]	-44.0	113.9	91.3	92.2
Range of SR, steer/ha	.82	1.01	1.48	1.48
Difference over range of SR, kg/ha	-36	115	135	137
---------- LS Means, kg/ha ----------				
Karl	110.1	216.5	--	--
2163	115.7	--	--	--
2180	128.6	219.1	234.4	189.3
AgSeCo 7853	89.9	216.5	209.9	187.4
Longhorn	--	--	232.0	199.7
Scout 66	--	--	240.7	186.6
SE	11.80	6.08	11.54	7.26

†= P < .10; * = P < .05; ** = P < .01; *** = P < .001.

[a]Change in grain yield (kg/ha) for each unit change in SR (steer/ha)

Table 5. Effect of wheat variety and stocking rate on grain yield (kg/ha).

Year	1 (92/93)	2 (93/94)	3 (94/95)	4 (96/97)
Variety	.81	.18	**	***
Stocking Rate (SR)	**	**	.37	*
Variety * SR	.78	.14	.59	.99
Y-intercept for SR, kg	3013	2492	655	2170
Regression Coefficient for SR[a]	-912	-403	73	-409
Range of SR, steer/ha	.82	1.01	1.48	1.48
Difference over range of SR, kg/ha	-747	-407	108	-672
----- LS Means, kg/ha -----				
Karl	1515.1	1864.7	--	--
2163	1686.5	--	--	--
2180	1684.8	1626.3	1263.8	--
AgSeCo 7853	1552.1	1549.7	1319.6	2499.8
Longhorn	--	--	959.2	1954.7
Scout 66	--	--	776.2	1553.9
SE	156.44	62.71	84.38	104.50

†= $P < .10$; * = $P < .05$; ** = $P < .01$; *** = $P < .001$.

[a]Change in grain yield (kg/ha) for each unit change in SR (steer/ha)

Table 6. In vivo digestible organic matter content of wheat forage by sampling date[a].

	Variety									
Date	Karl	2163	2180	AgSeCo 7853	Longhorn	Scout 66	SE	Variety	SR	SR x Variety
Year 1993-94										
Oct. 28	75.8	76.0	75.1	75.5	--	--	0.38	.38	.37	.58
Dec. 14	73.0	74.5	73.0	72.3	--	--	0.32	.06	.01	.07
Feb. 1	72.3	73.8	73.5	71.5	--	--	0.57	.06	.01	.74
Year 1994-95										
Nov. 1	--	--	73.4	73.9	73.3	73.7	0.38	.71	.22	.72
Dec. 12	--	--	76.4	74.5	75.3	75.0	1.25	.73	.17	.34
Jan. 24	--	--	73.8	69.9	73.5	71.4	1.50	.27	.01	.56
Pull-off[a]	--	--	73.0	69.6	71.3	70.9	0.68	.10	.01	.05
Year 1996-97										
Oct. 24	--	--	70.2[d]	70.9[c,d]	72.2[c]	70.9[c,d]	0.47	.03	.62	.92
Dec. 5	--	--	75.2[c]	72.1[c]	73.2[c]	67.2[d]	1.18	.01	.03	.01
Jan. 24	--	--	70.1[d]	70.8[c,d]	71.4[c]	68.5[e]	0.38	.01	.01	.01
Feb.24	--	--	66.9[d]	70.0[c]	70.5[c]	66.8[d]	0.77	.01	.01	.01

[a]Estimated in vivo digestibility values calculated using in vitro organic matter disappearance by in vivo conversion factors determined using known standards.
[b]Pull-off dates were: 2/25 for 2180; 3/6 for AgSeCo and Longhorn; 3/15 for Scout 66.
[c,d]Within a row, means lacking a common superscript letter differ (P < .05).

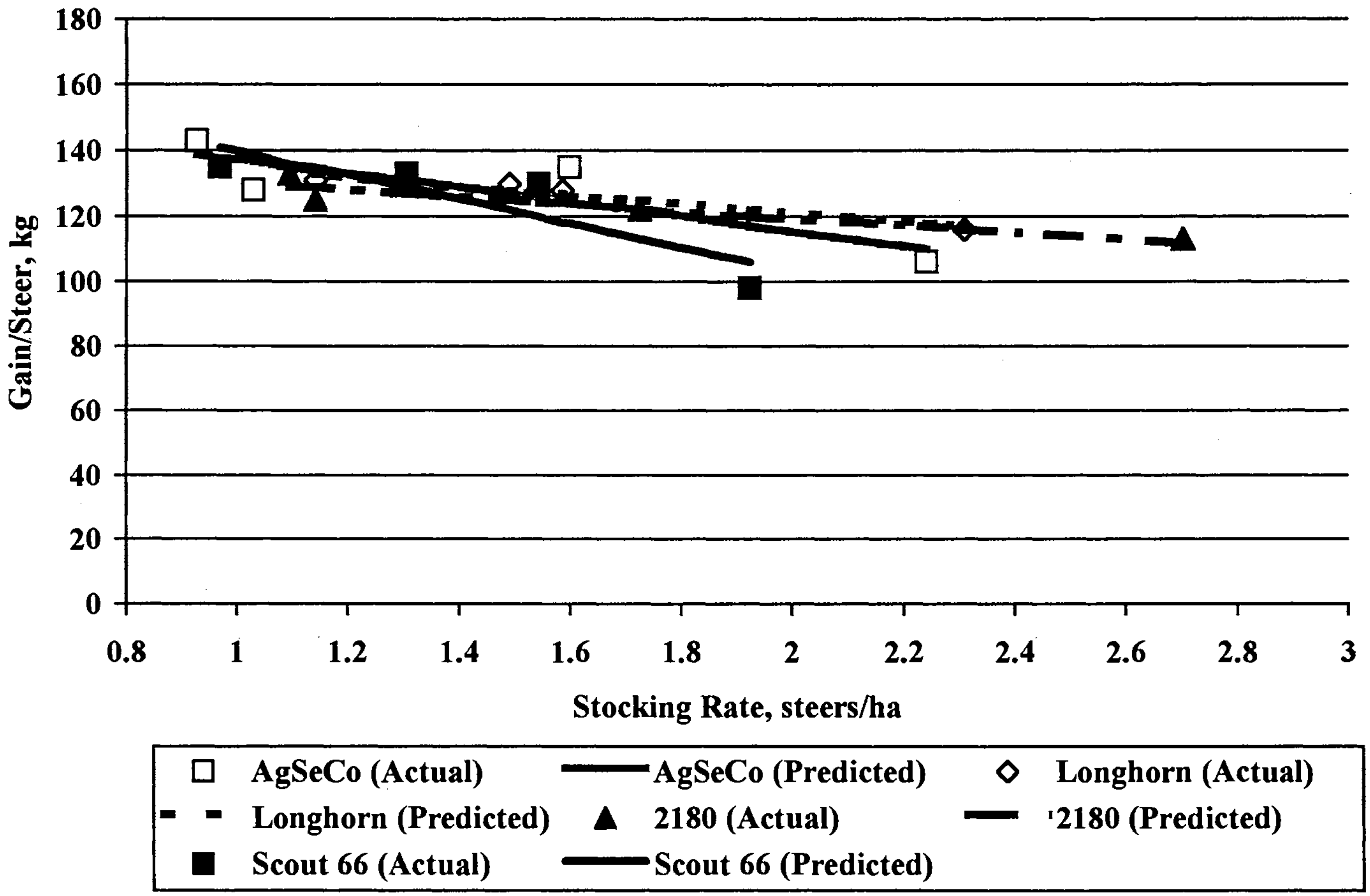

Figure 1. Weight gain per steer for variety x stocking rate study, Year 4 (1996-97)

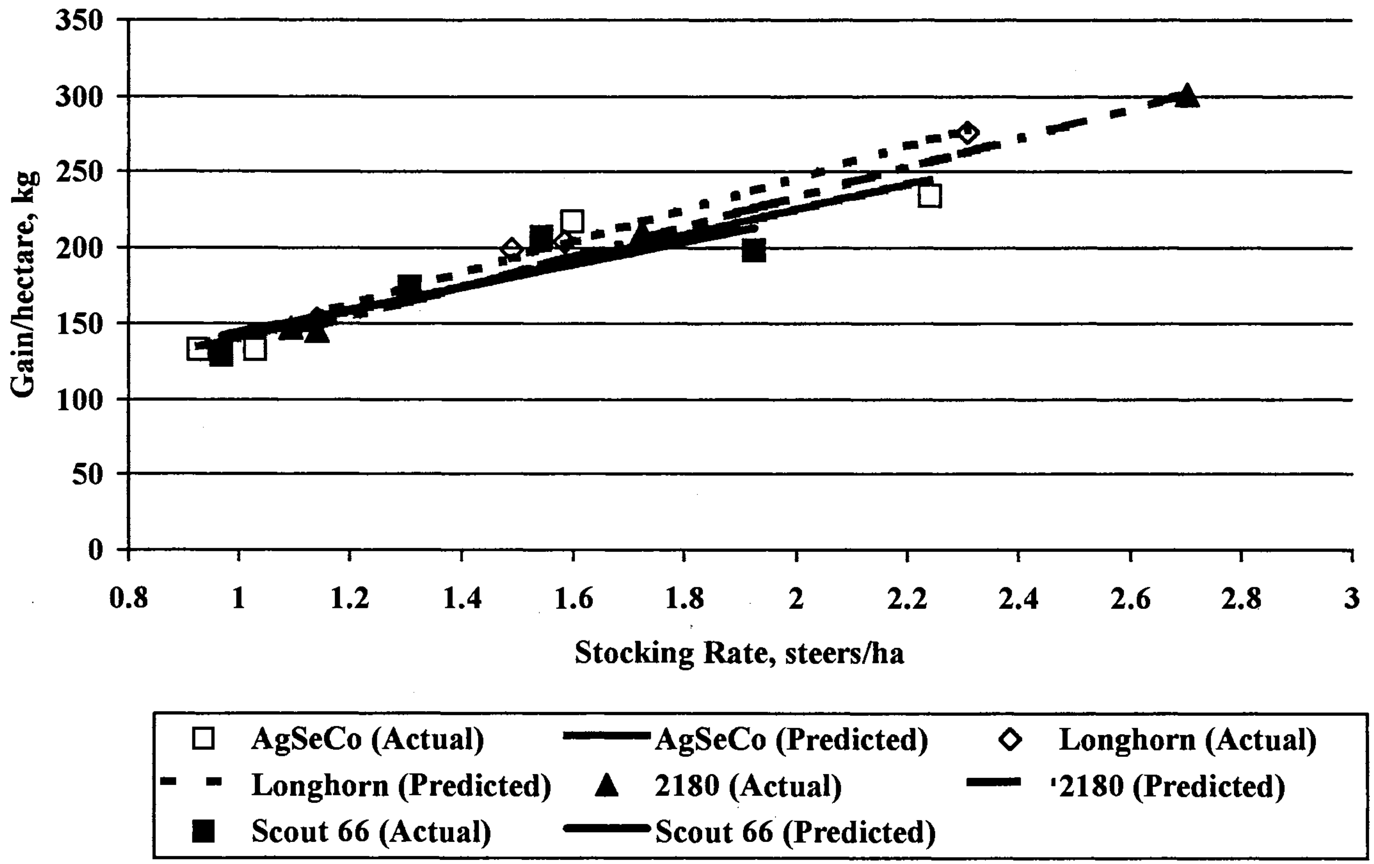

Figure 2. Gain per hectare for variety x stocking rate study, year 4 (1996-97)

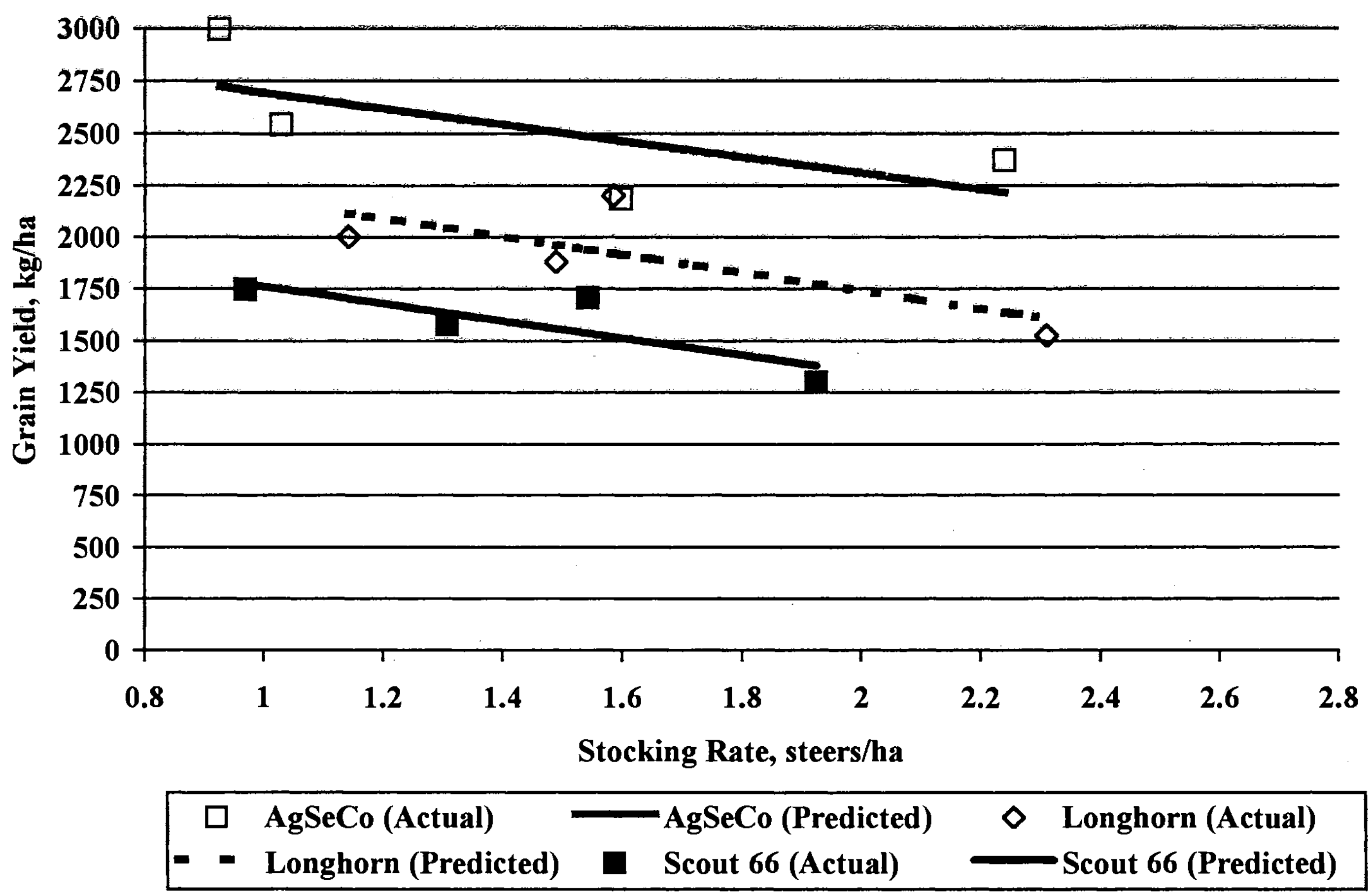

Figure 3. Grain yield for variety by stocking rate study, year 4 (1996-97).

APPENDICES

APPENDIX A

Individual Pasture Gain/Steer, Gain/Hectare, and Grain

Yield Data by Period for Crop Years 1992-93,

1993-94, 1994-95 and 1996-97

Table 1. Animal performance by period and grain yield for variety x stocking rate grazing trials 1992-93

Wheat Variety	Karl				2163				2180				AgSeCo 7853			
Steers/ha	1.24	1.51	1.78	2.05	1.24	1.51	1.78	2.05	1.24	1.51	1.78	2.05	1.24	1.51	1.78	2.05
Pasture	1	13	4	11	9	7	12	3	16	10	14	6	5	2	15	8
Pasture size, ha	9.72	7.29	7.29	7.29	9.72	7.29	7.29	7.29	9.72	7.29	7.29	7.29	9.72	7.29	7.29	7.29
Number of steers	12	11	13	15	12	11	13	15	12	11	13	15	12	11	13	15
Daily gains, kg																
Per. 1, 11/18 to 1/27	0.81	0.84	0.66	0.74	0.91	0.93	0.80	0.60	0.95	0.82	0.73	0.72	0.79	0.60	0.50	0.64
Per. 2, 1/27 to 3/10	0.83	0.60	0.05	0.09	1.14	0.77	0.35	-0.40	1.05	0.93	0.54	-0.05	0.73	0.37	-0.01	0.14
Total, 11/18 to 3/10	0.82	0.75	0.44	0.50	1.00	0.87	0.63	0.23	0.99	0.86	0.66	0.43	0.77	0.52	0.31	0.45
Weight gain/steer, kg																
Per. 1, 11/18 to 1/27	57	59	47	52	64	65	56	42	67	58	51	51	55	43	35	45
Per. 2, 1/27 to 3/10	35	25	2	4	48	33	15	-17	44	39	23	-2	31	15	0	6
Total, 11/18 to 3/10	92	83	49	56	112	98	71	25	111	97	74	48	86	58	35	50
Weight gain/ha, kg																
Per. 1, 11/18 to 1/27	71	89	83	107	79	99	100	86	82	86	92	104	69	64	63	92
Per. 2, 1/27 to 3/10	43	38	3	8	60	49	26	-35	55	58	40	-4	38	24	-1	11
Total, 11/18 to 3/10	113	126	86	115	138	147	126	52	137	146	131	100	107	88	62	103
Grain yield, kg/ha	2157	1216	1660	1028	2002	2345	1203	1196	1801	1875	1781	1283	1700	1935	1223	1351

Table 2. Animal performance by period and grain yield for variety x stocking rate grazing trials 1993-94

Wheat variety	Karl				2163				2180				AgSeCo 7853			
Steers/ha	1.04	1.51	1.78	2.05	1.04	1.51	1.78	2.05	1.04	1.51	1.78	2.05	1.04	1.51	1.78	2.05
Pasture	16	6	14	2	5	15	8	10	1	11	13	4	9	3	7	12
Pasture size, ha	9.71	7.28	7.28	7.28	9.71	7.28	7.28	7.28	9.71	7.28	7.28	7.28	9.71	7.28	7.28	7.28
No. of steers	10	11	13	15	10	11	13	15	10	11	13	15	10	11	13	15
Initial weight, kg	226	227	229	223	232	226	233	229	222	226	230	227	231	221	232	227
Daily gains, kg																
Per. 1, 11/2 to 12/16	0.90	0.99	1.09	0.90	1.02	0.77	0.94	1.04	0.92	0.97	0.92	0.91	0.89	0.90	1.02	0.92
Per. 2, 12/16 to 2/3	1.32	1.37	1.46	1.50	1.37	1.44	1.45	1.53	1.51	1.49	1.45	1.40	1.50	1.45	1.43	1.38
Per. 3, 2/3 to 3/15	0.90	0.68	0.70	0.57	0.81	0.99	0.88	0.62	1.04	0.82	0.69	0.34	0.84	0.73	0.56	0.52
Total, 11/2 to 3/15	1.05	1.04	1.11	1.02	1.09	1.08	1.11	1.10	1.17	1.11	1.05	0.92	1.10	1.05	1.04	0.97
Weight gain/steer, kg																
Per. 1, 11/2 to 12/16	40	44	48	40	45	34	41	46	40	43	40	40	39	40	45	40
Per. 2, 12/16 to 2/3	65	67	71	73	67	70	71	75	74	73	71	69	74	71	70	68
Per. 3, 2/3 to 3/15	36	27	28	23	32	40	35	25	41	33	28	14	33	30	23	21
Total, 11/2 to 3/15	140	138	148	135	145	144	147	145	156	148	139	122	146	140	138	129
Weight gain/ha, kg																
Per. 1, 11/2 to 12/16	40	66	85	81	46	46	74	94	42	64	72	83	40	60	80	83
Per. 2, 12/16 to 2/3	66	101	128	152	70	97	127	155	76	110	127	142	76	108	126	139
Per. 3, 2/3 to 3/15	37	42	51	47	34	54	63	52	43	49	49	28	35	44	40	43
Total, 11/2 to 3/15	145	208	264	280	148	198	263	300	161	224	248	252	151	211	246	266
Grain yield, kg/ha	1922	1996	1720	1707	2002	2170	1391	1606	2016	1707	1411	1324	1727	1424	1639	1391

Table 3. Animal performance by period and grain yield for variety x stocking rate grazing trials 1994-95

Wheat Variety	2180				AgSeCo 7853				Longhorn				Scout 66			
Stocking rate, str/ha	0.96	1.41	1.88	2.25	0.89	1.09	1.61	2.30	0.99	1.46	1.78	2.82	1.06	1.31	1.93	2.27
PastureP	5	10	15	3	16	4	8	11	1	12	7	14	9	6	13	2
Pasture size, ha	9.71	7.28	7.28	7.28	9.71	7.28	7.28	7.28	9.71	7.28	7.28	7.28	9.71	7.28	7.28	7.28
Daily gains, kg																
Per. 1, 11/1 to 12/16	0.78	0.99	0.89	0.87	0.86	0.85	0.87	0.82	0.92	0.82	0.92	0.86	0.75	0.96	0.95	0.88
Per. 2, 12/16 to 1/27	1.39	1.58	1.44	1.33	1.40	1.33	1.39	1.17	1.63	1.47	1.48	1.41	1.44	1.43	1.39	1.17
Per. 3, 1/27 to pull-off*	1.11	1.50	1.18	0.90	1.22	1.16	1.23	0.64	1.24	1.09	1.20	0.46	1.15	1.31	1.10	0.65
Total, 11/1 to pull-off	1.09	1.33	1.16	1.05	1.15	1.10	1.15	0.89	1.25	1.12	1.19	0.93	1.10	1.23	1.14	0.89
Weight gain/steer, kg																
Per. 1, 11/1 to 12/16	35	44	40	39	39	38	39	37	41	37	41	39	34	44	43	40
Per. 2, 12/16 to 1/27	58	66	60	56	59	56	58	50	69	62	62	60	60	60	58	49
Per. 3, 1/27 to pull-off*	33	44	34	26	46	44	47	24	47	41	45	18	55	62	52	30
Total, 11/1 to pull-off	126	154	134	121	144	138	144	110	157	140	149	116	149	165	153	119
Weight gain/ha, kg																
Per. 1, 11/1 to 12/16	31	53	66	91	33	42	58	83	38	46	67	97	31	52	72	98
Per. 2, 12/16 to 1/27	60	91	117	122	54	61	104	115	71	93	119	180	69	83	120	108
Per. 3, 1/27 to pull-off*	34	77	75	58	43	48	71	56	48	67	81	54	62	85	107	67
Total, 11/1 to pull-off	125	221	258	272	129	151	234	254	157	207	267	330	162	220	299	273
Grain yield, kg/ha	1465	1209	1283	1337	1041	1411	1310	1458	900	1196	887	880	517	934	860	786

Pull-off dates were: 2/25 for 2180; 3/6 for AgSeCo and Longhorn; 3/15 for Scout 66.

Table 4. Animal performance by period and grain yield for variety x stocking rate grazing trials 1996-97

Variety	2180				AgSeCo 7853				Longhorn				Scout 66			
Steers/hectare	1.14	1.09	1.72	2.70	0.93	1.03	1.60	2.24	1.14	1.49	1.59	2.31	0.97	1.31	1.54	1.92
Pasture	9	3	11	14	1	6	15	10	16	12	2	7	5	13	8	4
Pasture size, ha	9.72	7.29	7.29	7.29	9.72	7.29	7.29	7.29	9.72	7.29	7.29	7.29	9.72	7.29	7.29	7.29
Avg avail forage kg/steer	5950	4631	3607	2230	6121	4775	3329	2195	5673	4462	3142	2001	6041	4807	3255	1955
Daily gains, kg/steer																
Per. 1, 10/25 to 12/11	0.92	1.00	1.08	1.02	0.87	0.90	0.89	1.02	0.84	0.90	1.02	1.16	0.90	0.95	0.95	0.97
Per. 2, 12/11 to 1/24	1.28	1.26	1.29	1.22	1.25	1.05	1.27	1.09	1.33	1.28	1.25	1.24	1.26	1.20	1.25	0.82
Per. 3, 1/24 to 2/24	0.84	1.00	0.47	0.36	1.10	1.01	0.88	0.49	1.06	1.00	0.81	0.22	0.89	0.74	0.65	0.43
Per. 4, 2/24 to 3/8					1.05	0.73	0.88	-0.40					0.79	1.08	0.93	0.25
Total, 10/25 to pull-off	1.03	1.09	1.00	0.92	1.06	0.95	1.01	0.79	1.07	1.06	1.05	0.95	1.00	1.00	0.97	0.73
Weight gain/steer, kg																
Per. 1, 10/25 to 12/11	43	47	51	48	41	42	41	48	40	42	48	55	42	45	45	45
Per. 2, 12/11 to 1/24	56	55	56	54	55	46	56	48	59	56	55	55	55	53	55	36
Per. 3, 1/24 to 2/24	26	31	15	11	34	31	27	15	33	31	25	7	27	23	20	13
Per. 4, 2/24 to 3/8					13	9	10	-5					10	13	11	3
Total, 10/25 to pull-off	125	133	122	113	143	128	135	106	131	130	128	116	135	133	130	98
Weight gain/ha, kg/ha																
Per. 1, 10/25 to 12/11	40	45	84	105	38	41	62	105	37	58	73	120	39	49	67	100
Per. 2, 12/11 to 1/24	70	69	101	163	51	57	92	106	72	93	91	142	51	72	98	70
Per. 3, 1/24 to 2/24	35	34	26	33	32	26	45	35	44	47	41	14	28	34	27	24
Per. 4, 2/24 to 3/8					12	9	17	-12					11	18	13	4
Total, 10/25 to pull-off	145	147	210	301	133	133	217	234	153	199	204	276	129	174	207	198
Grain yield, kg/ha	900	679	1310	921	2997	2540	2184	2372	2002	1881	2204	1525	1747	1579	1707	1297

APPENDIX B

Crude Protein and Forage Digestibility Estimates of Hand-Clipped

Diet Quality Samples During Crop Years

1993-94, 1994-95 and 1996-97

Table 1. Crude protein, in vitro OMD, in vivo OMD and in vivo DOM values of wheat forage samples collected during 1993-94

Variety	Karl				2163				2180				AgSeCo 7853			
Steers/hectare	1.04	1.51	1.78	2.05	1.04	1.51	1.78	2.05	1.04	1.51	1.78	2.05	1.04	1.51	1.78	2.05
Pasture	16	6	14	2	5	15	8	10	1	11	13	4	9	3	7	12
	Oct. 28, 1993															
CP, %	26.58	25.92	26.81	26.25	26.79	29.32	27.04	28.02	27.85	28.68	28.82	28.11	28.70	27.31	27.80	28.65
In Vitro OMD, %	92.82	93.97	92.80	92.42	92.74	92.16	94.17	93.60	91.66	92.52	93.24	92.32	93.96	91.98	94.06	92.72
In Vivo OMD, %	83.93	84.60	83.92	83.69	83.88	83.54	84.72	84.39	83.25	83.75	84.17	83.63	84.59	83.44	84.65	83.87
In Vivo DOM, %	75.71	76.13	76.13	75.06	75.58	74.81	77.14	76.61	74.12	75.49	75.98	74.77	75.73	74.82	76.05	75.37
	Dec. 14, 1993															
CP, %	22.71	24.10	22.09	22.28	26.73	27.45	28.03	27.47	28.43	27.89	25.88	27.46	28.92	26.36	27.52	25.20
In Vitro OMD, %	89.58	87.78	88.19	85.38	89.00	90.07	89.47	88.03	87.45	88.45	88.35	87.12	85.77	86.75	86.92	88.65
In Vivo OMD, %	82.03	80.97	81.21	79.57	81.69	82.31	81.97	81.12	80.78	81.37	81.31	80.59	79.79	80.37	80.47	81.48
In Vivo DOM, %	74.54	74.20	72.48	70.70	74.80	74.68	75.18	73.45	73.20	73.55	72.47	72.87	72.22	72.61	72.39	71.90
	Feb. 1, 1994															
CP, %	16.89	17.08	17.60	17.70	17.62	18.19	17.76	17.39	18.53	18.37	18.02	19.81	18.76	19.60	19.31	19.17
In Vitro OMD, %	88.05	84.46	87.22	84.01	88.68	88.23	85.12	87.40	87.97	87.66	87.55	85.27	87.08	85.18	83.56	84.98
In Vivo OMD, %	81.13	79.03	80.64	78.76	81.50	81.24	79.41	80.75	81.09	80.90	80.84	79.50	80.56	79.45	78.50	79.33
In Vivo DOM, %	75.07	71.28	73.15	70.31	75.18	74.32	71.85	73.54	74.61	74.19	73.72	71.27	73.46	72.27	69.74	70.69

Table 2. Crude protein, in vitro OMD, in vivo OMD and in vivo DOM values of wheat forage samples collected during 1994-95

Variety	2180				AgSeCo 7853				Longhorn				Scout 66			
Steers/hectare	0.96	1.41	1.88	2.25	0.89	1.09	1.61	2.30	0.99	1.46	1.78	2.82	1.06	1.31	1.93	2.27
Pasture	5	10	15	3	16	4	8	11	1	12	7	14	9	6	13	2
	---------- Nov 1, 1994 ----------															
CP, %	30.13	31.58	31.01	29.92	31.59	29.43	30.83	31.02	27.96	28.42	27.37	28.13	29.76	28.52	29.64	28.95
In Vitro OMD, %	91.37	89.84	91.31	92.92	91.25	93.79	92.96	91.46	92.08	89.59	91.29	89.77	90.45	93.30	90.41	92.41
In Vivo OMD, %	82.11	81.13	82.07	83.09	82.03	83.64	83.12	82.47	82.56	80.98	82.06	81.09	81.52	83.33	81.50	82.77
In Vivo DOM, %	73.05	72.33	74.00	74.30	72.98	74.26	74.31	73.74	73.83	72.74	73.15	73.50	72.78	74.87	73.00	74.18
	---------- Dec. 12, 1994 ----------															
CP, %	24.78	25.57	24.90	20.60	24.38	25.37	25.71	22.38	22.59	22.74	21.26	21.78	24.10	24.15	23.42	19.30
In Vitro OMD, %	90.46	92.61	92.41	89.88	86.04	87.78	90.38	92.38	88.26	91.86	89.39	89.58	90.85	85.89	91.51	90.07
In Vivo OMD, %	84.57	86.15	86.00	84.14	81.33	82.60	84.51	85.97	82.95	79.54	83.78	83.92	84.86	81.21	85.34	84.28
In Vivo DOM, %	76.92	78.50	78.25	72.08	73.46	74.12	76.81	74.17	75.99	73.16	76.28	75.59	77.73	73.60	78.15	70.13
	---------- Jan 24, 1995 ----------															
CP, %	24.60	23.98	22.00	19.60	24.09	25.22	24.93	22.48	20.92	21.87	19.88	18.65	24.51	23.61	23.46	19.22
In Vitro OMD, %	92.43	91.75	90.41	90.44	90.72	91.80	92.58	88.68	91.93	91.97	89.61	87.53	91.25	89.72	91.65	88.65
In Vivo OMD, %	85.26	84.76	83.76	83.79	84.00	84.79	85.38	82.47	84.90	84.93	83.17	81.62	84.39	83.25	84.68	82.45
In Vivo DOM, %	77.47	76.75	73.93	67.62	74.39	70.98	73.20	64.37	77.71	77.20	72.58	68.64	76.26	73.42	74.49	60.81
	---------- Mar 15, 1995 ----------															
CP, %	26.35	27.75	25.00	23.52	31.55	33.13	31.44	27.41	29.32	29.10	29.30	24.31	29.50	31.45	31.95	31.10
In Vitro OMD, %	92.39	91.29	87.58	91.01	90.22	91.73	87.65	88.11	90.37	87.81	88.50	82.96	83.66	89.02	81.78	89.90
In Vivo OMD, %	83.03	82.32	79.91	82.13	81.62	82.60	79.96	80.26	81.72	80.06	80.51	76.92	77.37	80.84	76.15	81.41
In Vivo DOM, %	75.88	74.47	71.97	69.83	74.21	74.45	71.11	63.64	74.82	73.41	71.92	60.78	71.56	72.98	69.64	69.01

Table 3. In vitro OMD, in vivo OMD and in vivo DOM values of wheat forage samples collected during 1996-97

Variety	2180				AgSeCo 7853				Longhorn				Scout 66			
Steers/hectare	1.14	1.09	1.72	2.70	0.93	1.03	1.60	2.24	1.14	1.49	1.59	2.31	0.97	1.31	1.54	1.92
Pasture	9	3	11	14	1	6	15	10	16	12	2	7	5	13	8	4
	------ Oct 24, 1996 ------															
In Vitro OMD, %	87.10	88.92	80.01	86.43	88.98	87.26	89.53	88.30	88.74	89.38	89.24	89.09	86.98	82.42	90.46	86.55
In Vivo OMD, %	80.03	81.07	75.96	79.64	81.11	80.12	81.42	80.72	80.96	81.33	81.25	81.16	79.96	77.34	81.95	79.71
In Vivo DOM, %	70.34	71.79	67.37	71.05	70.80	70.40	72.01	70.41	72.97	72.50	71.44	71.79	71.18	69.25	73.05	70.34
	------ Dec. 5, 1996 ------															
In Vitro OMD, %	88.72	91.36	90.67	91.92	97.82	86.04	86.22	82.23	80.75	90.88	89.84	87.33	87.03	89.71	89.73	76.68
In Vivo OMD, %	80.95	82.47	82.07	82.79	86.17	79.42	79.52	77.24	76.39	82.19	81.60	80.16	79.98	81.52	81.54	74.06
In Vivo DOM, %	74.93	75.25	75.16	75.78	78.82	71.08	71.71	68.67	70.06	76.43	75.61	71.53	71.14	74.84	73.10	56.56
	------ Jan 24, 1997 ------															
In Vitro OMD, %	83.37	85.09	82.76	78.88	85.64	86.15	85.30	85.66	87.54	85.58	84.37	82.74	84.35	83.91	80.12	85.61
In Vivo OMD, %	77.89	78.88	77.54	75.31	79.19	79.48	78.99	79.20	80.28	79.15	78.46	77.53	78.45	78.20	76.03	79.17
In Vivo DOM, %	70.77	71.35	69.63	67.48	70.87	69.74	71.60	70.93	73.75	72.41	69.86	67.71	70.23	71.50	67.38	66.77
	------ Feb. 24, 1997 ------															
In Vitro OMD, %	84.34	88.52	77.97	83.05	86.04	85.88	91.59	86.42	90.72	87.10	88.30	85.42	86.82	89.50	85.21	87.47
In Vivo OMD, %	78.44	80.84	74.80	77.70	79.42	79.32	82.60	79.64	82.10	80.02	80.71	79.06	79.86	81.40	78.94	80.24
In Vivo DOM, %	70.47	72.01	62.44	58.97	70.87	67.88	74.50	67.22	75.20	71.44	70.49	60.72	70.92	73.96	64.25	62.66

APPENDIX C

Predicted Values vs Actual Observations Plotted Against Stocking

Rate for Daily Gains, Gain/Steer, Gain/Hectare, and

Grain Yield for Crop Years of 1992-93,

1993-94, 1994-95 and 1996-97

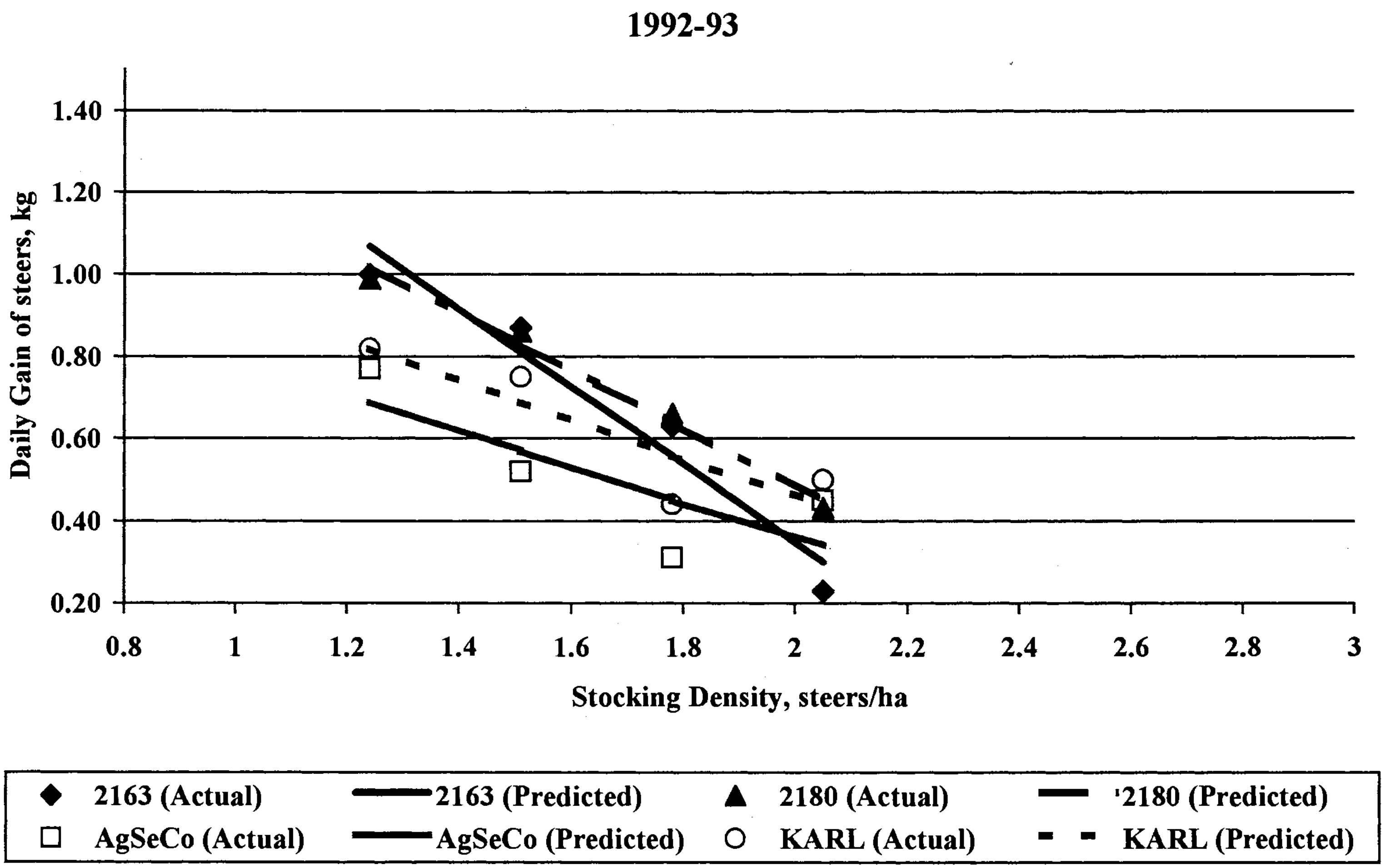

Figure 1. Daily gain of steers for variety x stocking rate study, year 1.

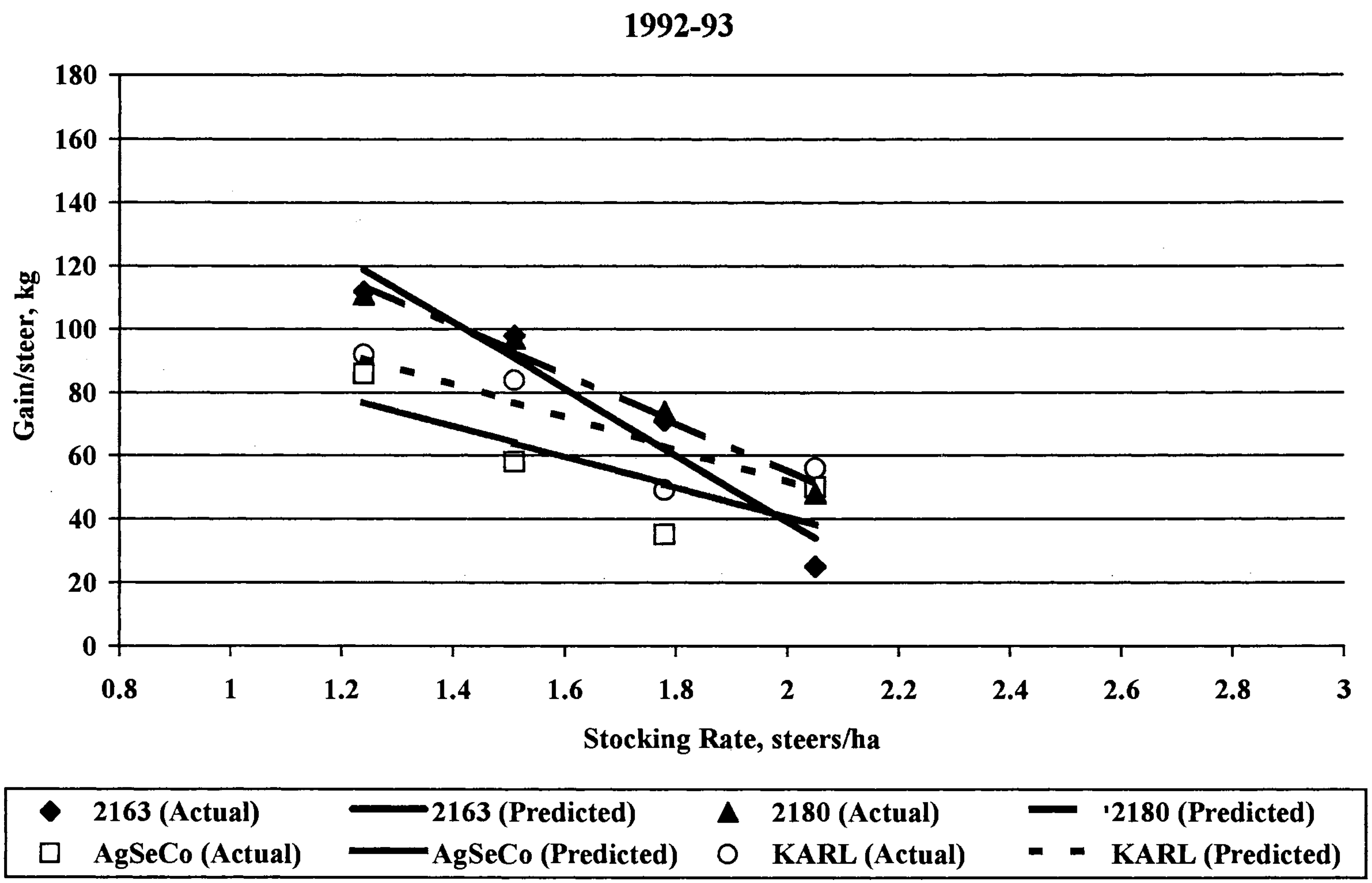

Figure 2. Gain/steer for variety by stocking rate study, year 1.

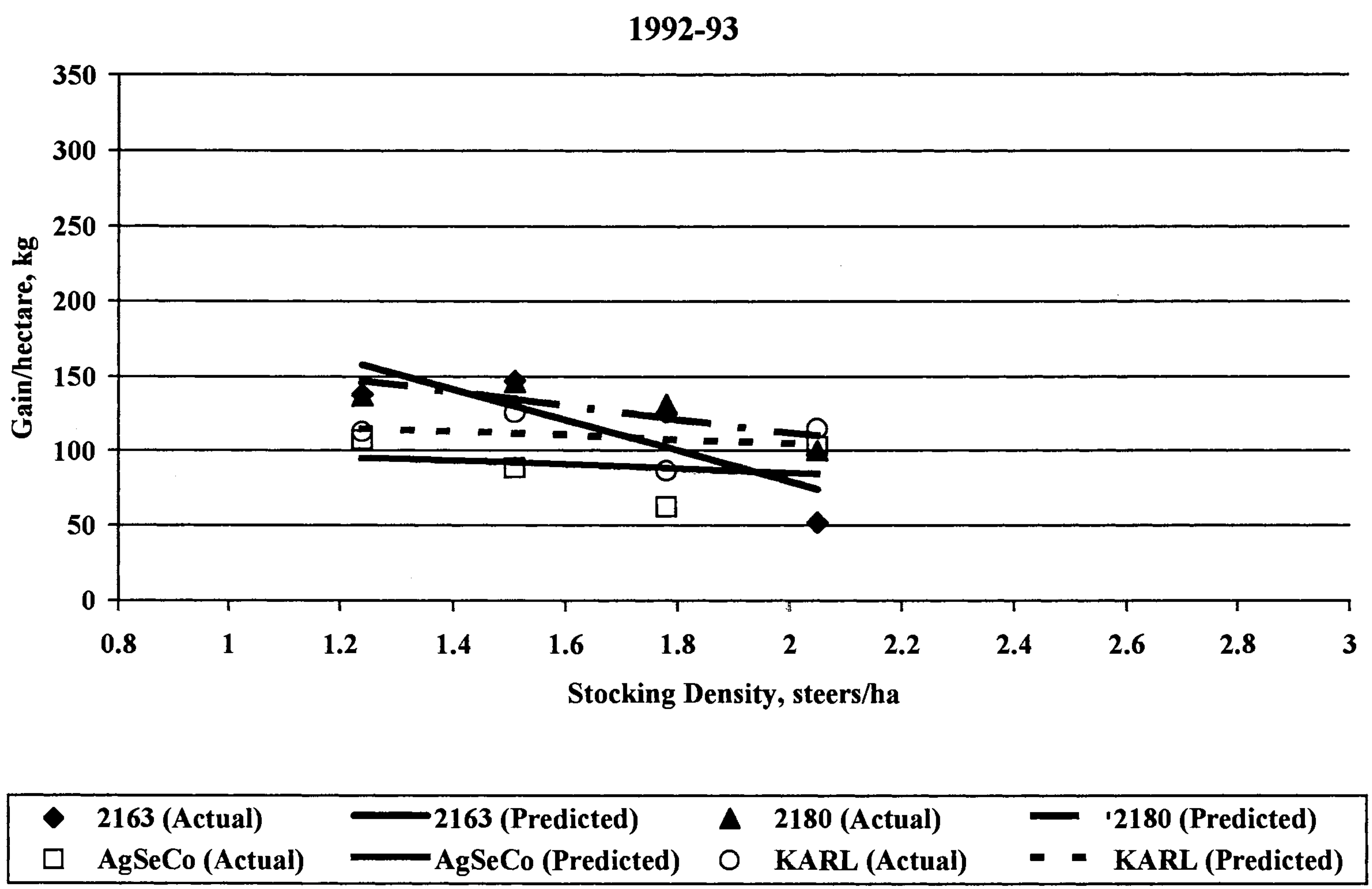

Figure 3. Gain/hectare for variety x stocking rate study, year 1.

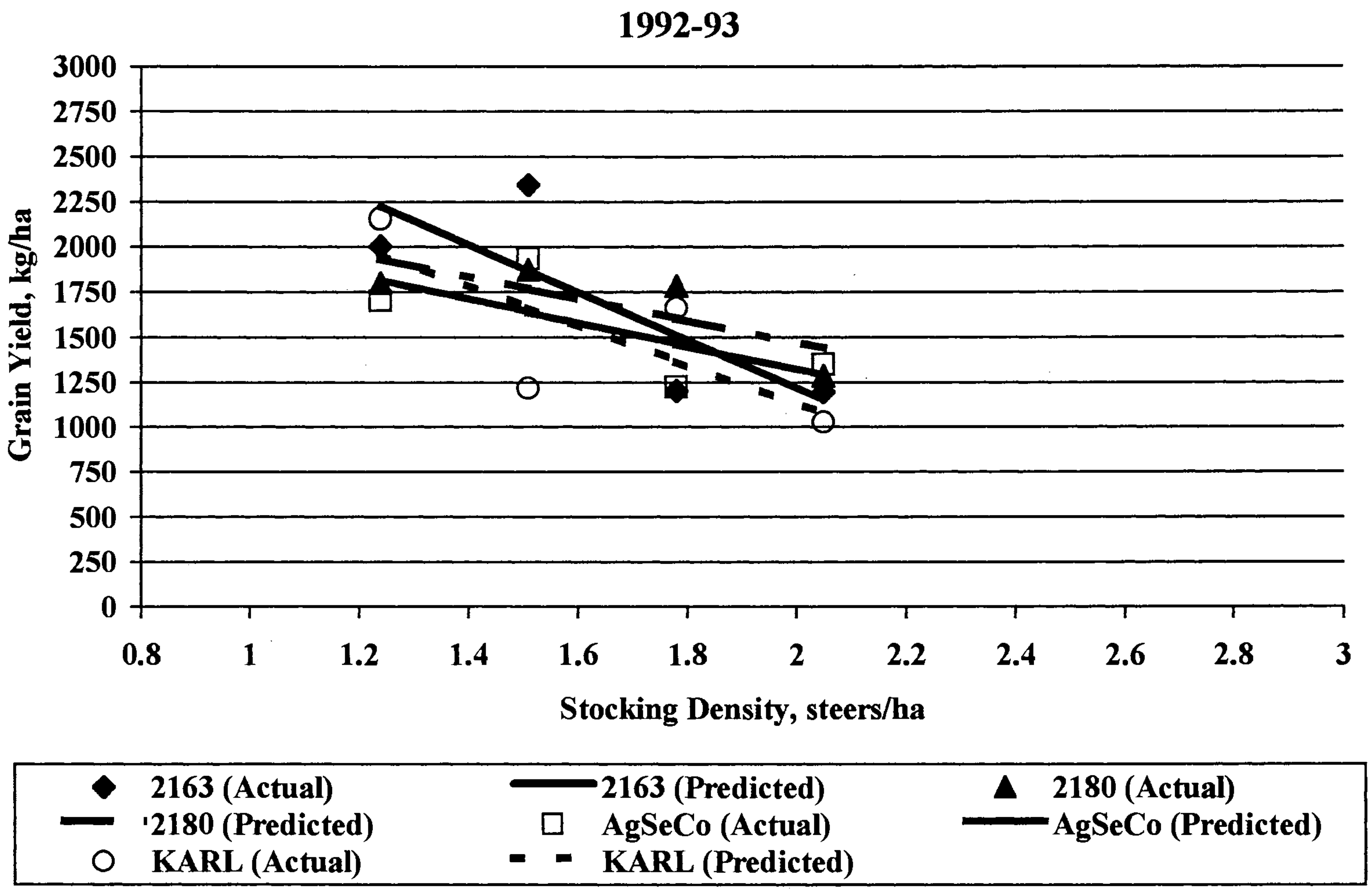

Figure 4. Grain production for variety x stocking rate study, year 1.

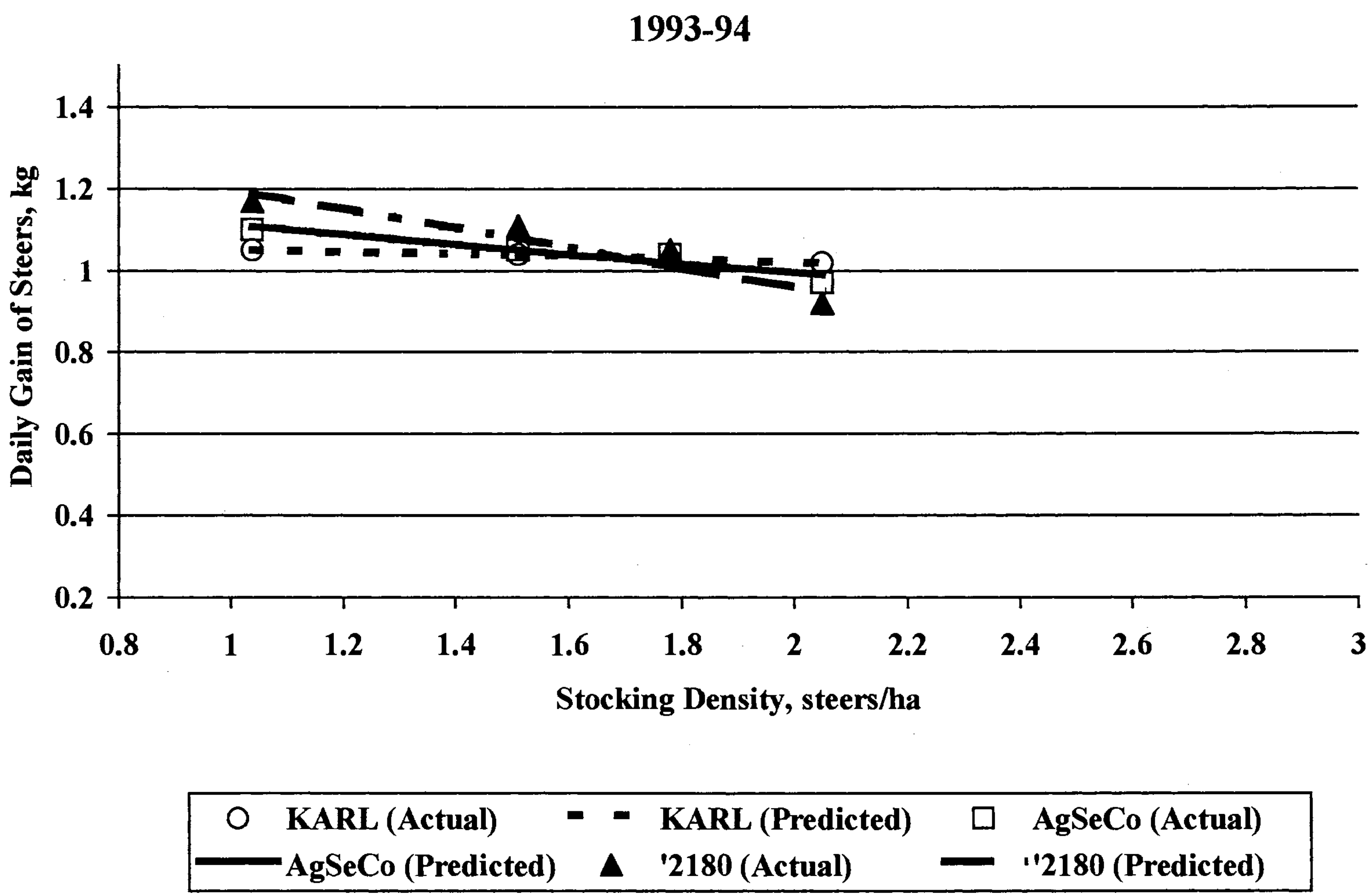

Figure 5. Daily gain of steers on variety x stocking rate study, year 2.

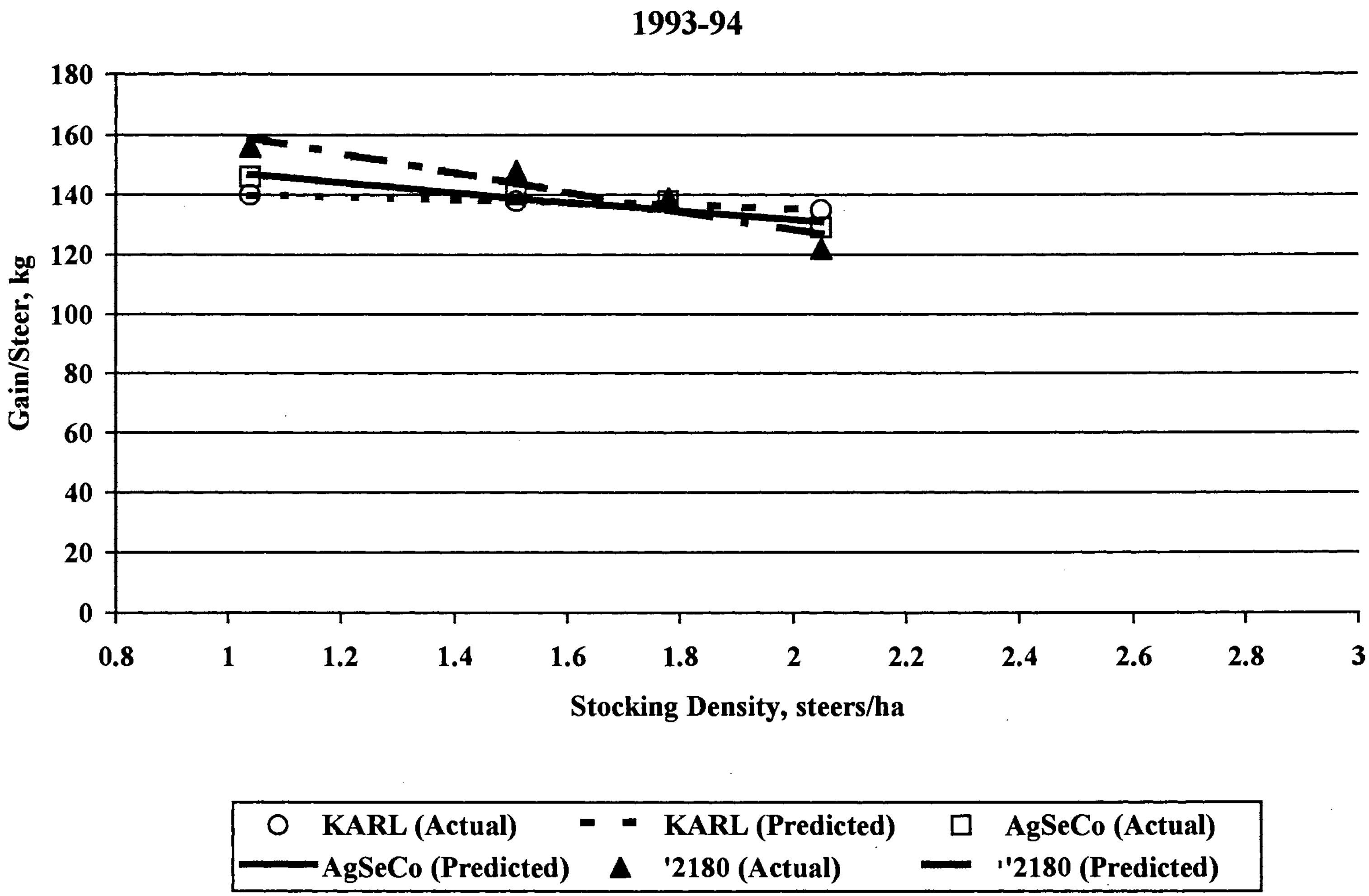

Figure 6. Gain/steer for variety by stocking rate study, year 2.

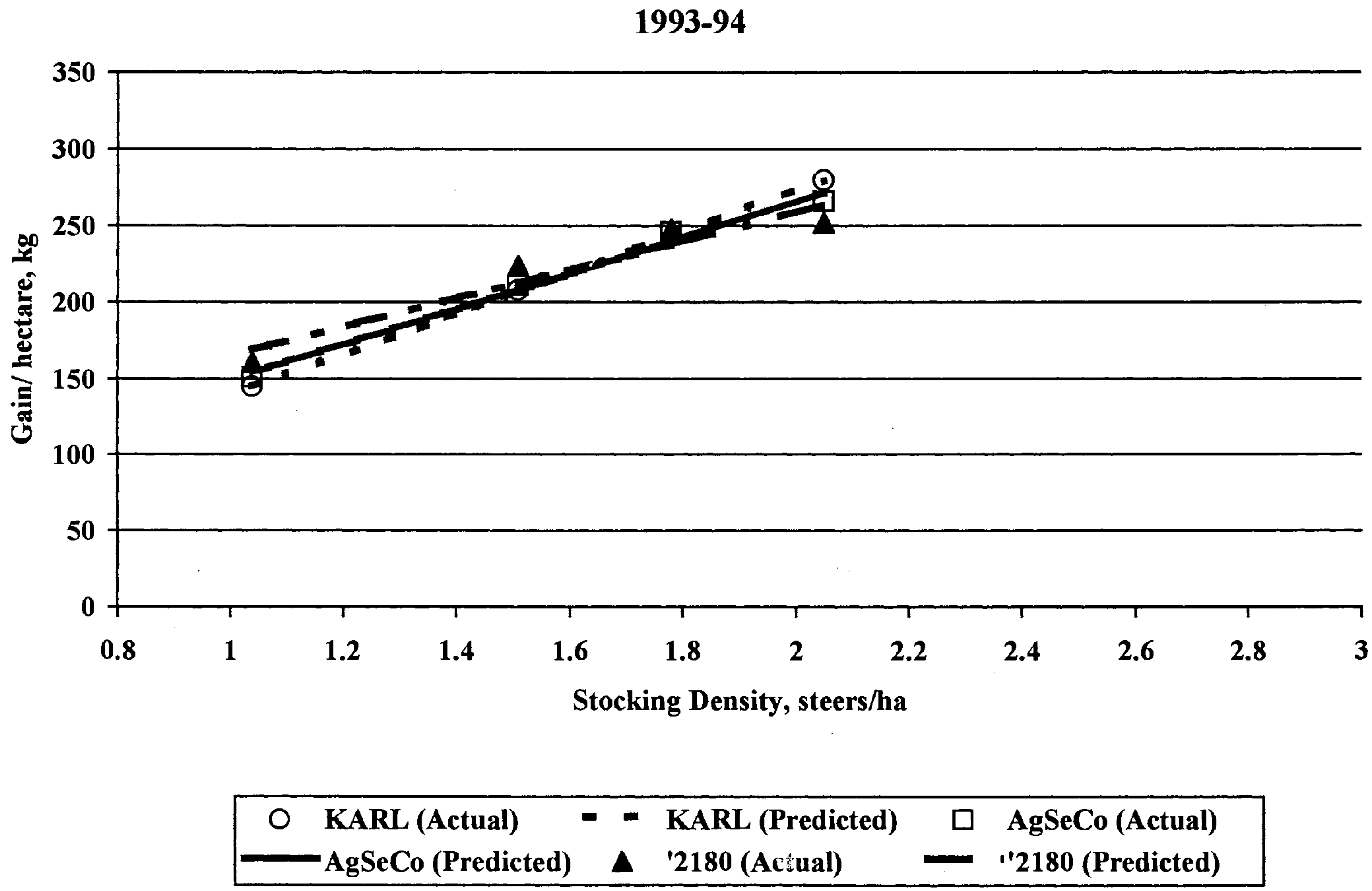

Figure 7. Gain/hectare for variety x stocking rate study, year 2.

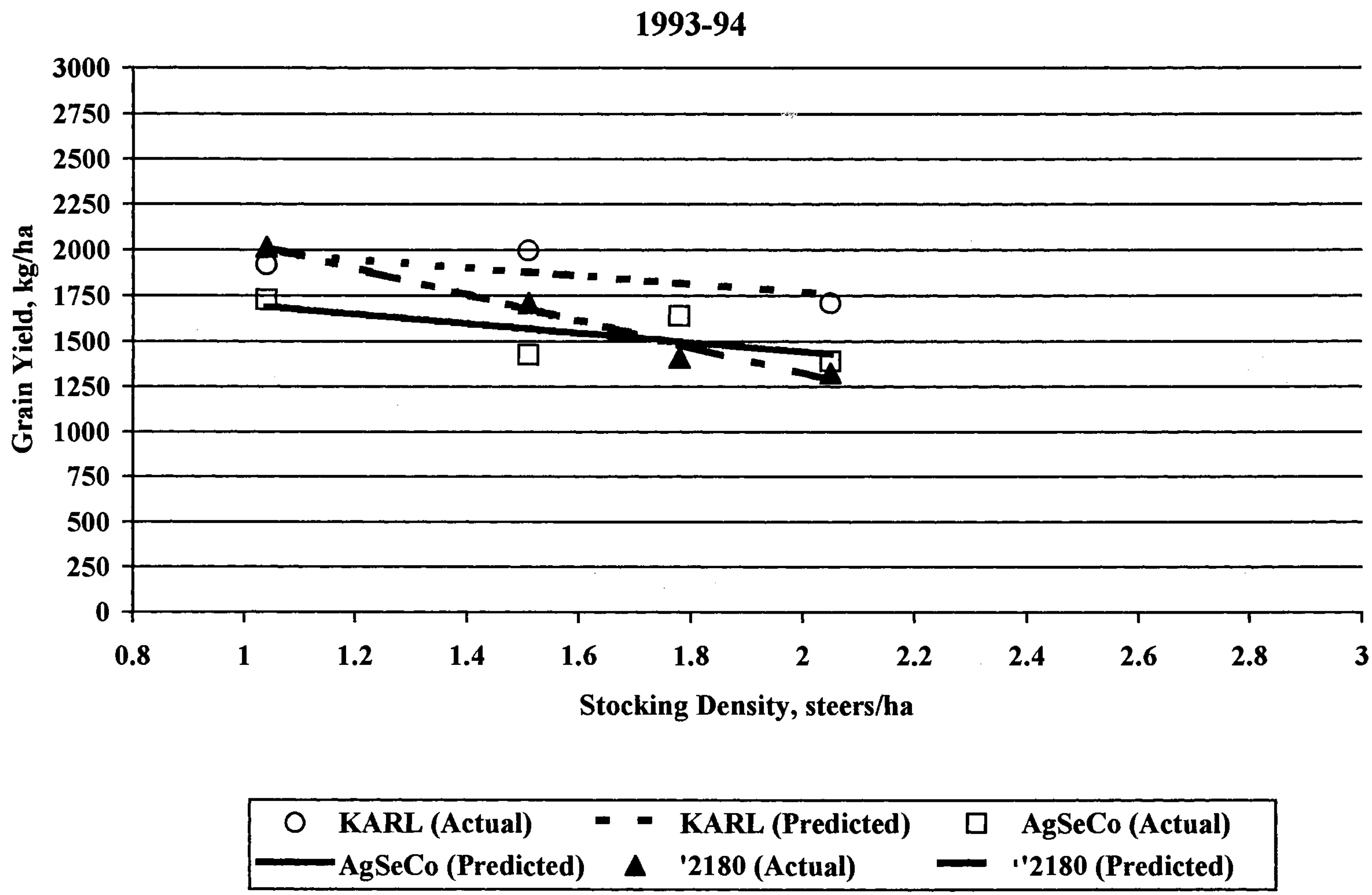

Figure 8. Grain production for variety x stocking rate study, year 2.

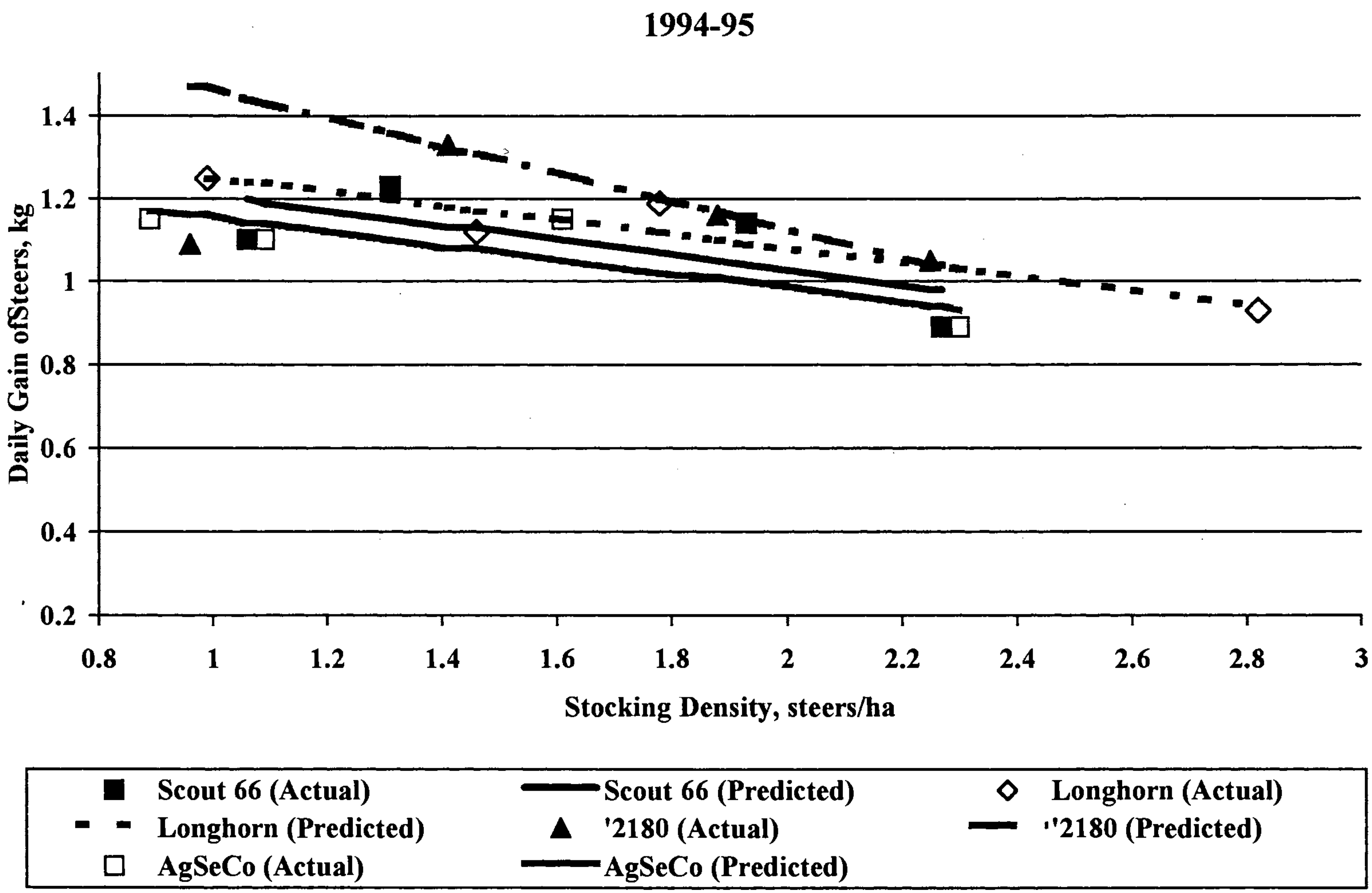

Figure 9. Daily gain of steers for variety x stocking rate study, year 3.

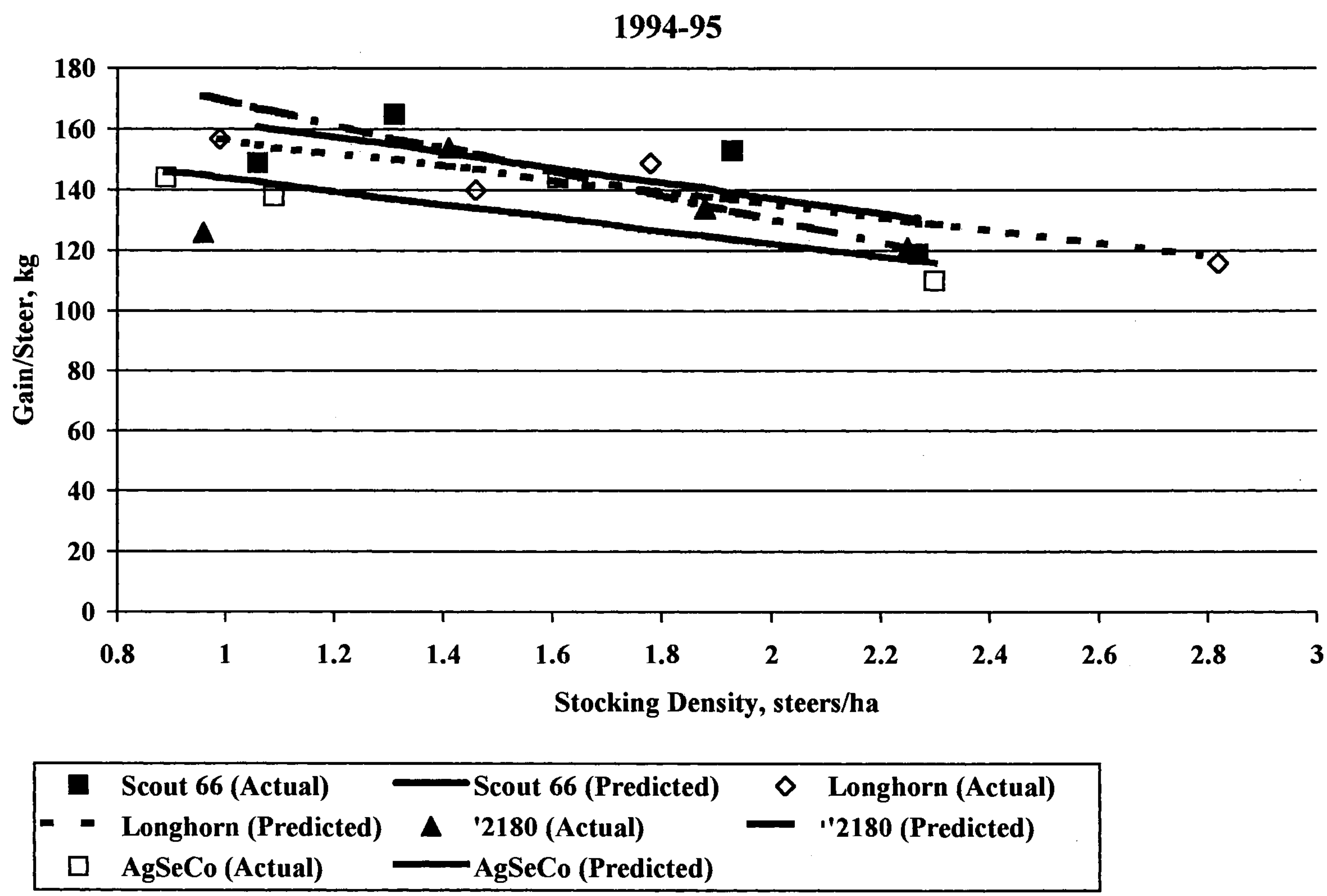

Figure 10. Gain/steer for variety x stocking rate study, year 3.

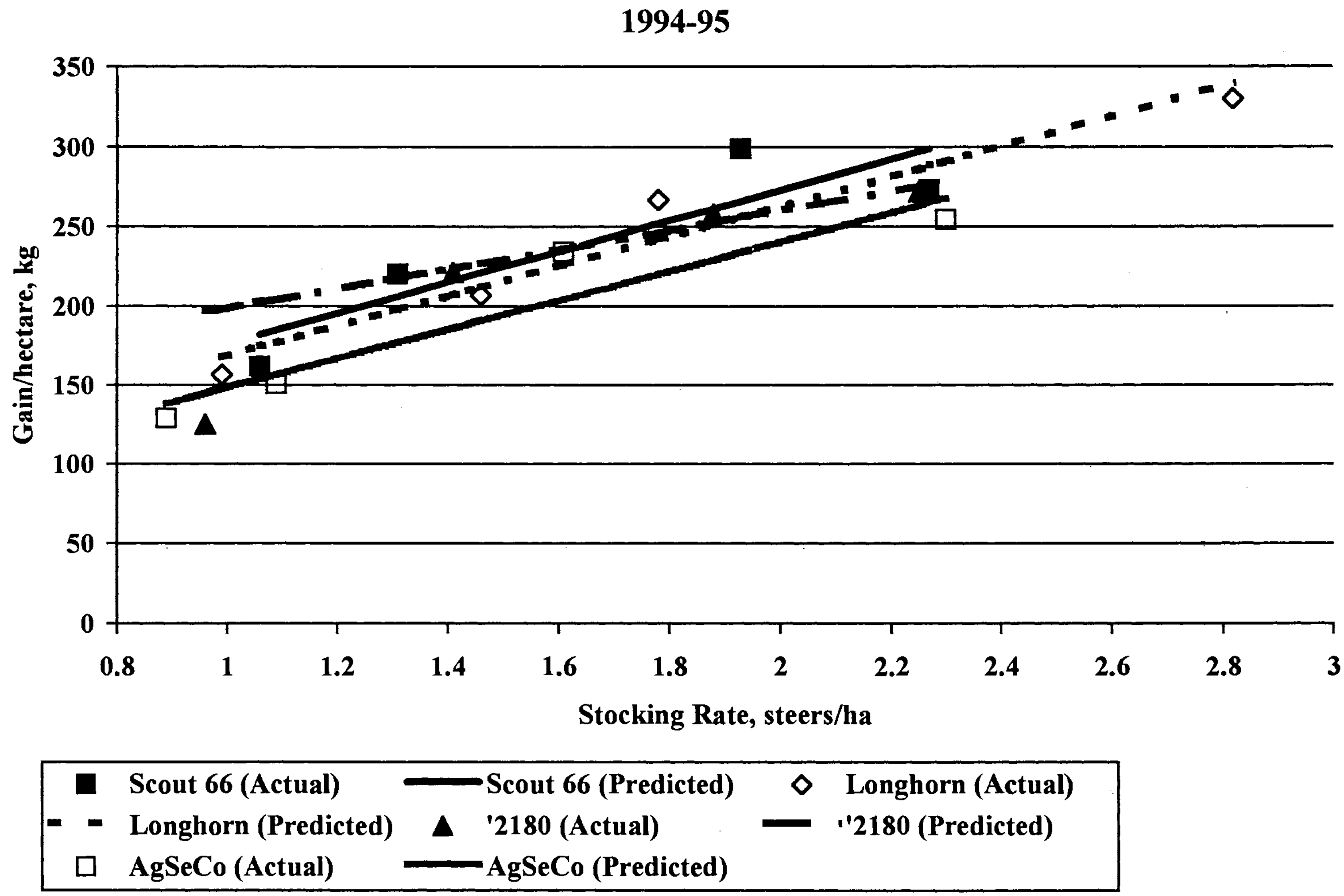

Figure 11. Gain/hectare for variety by stocking rate study, year 3.

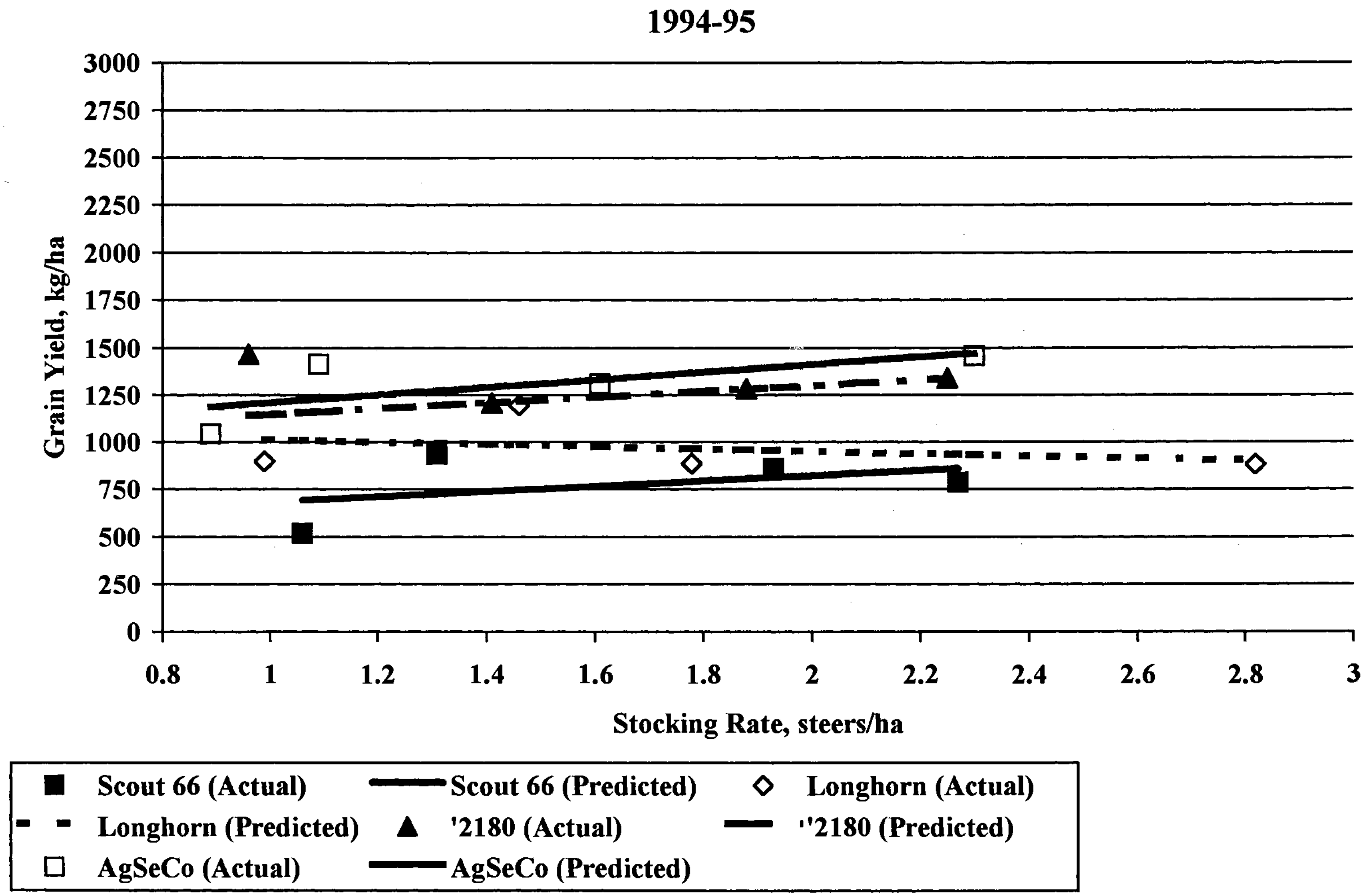

Figure 12. Grain production for variety x stocking rate study, year 3.

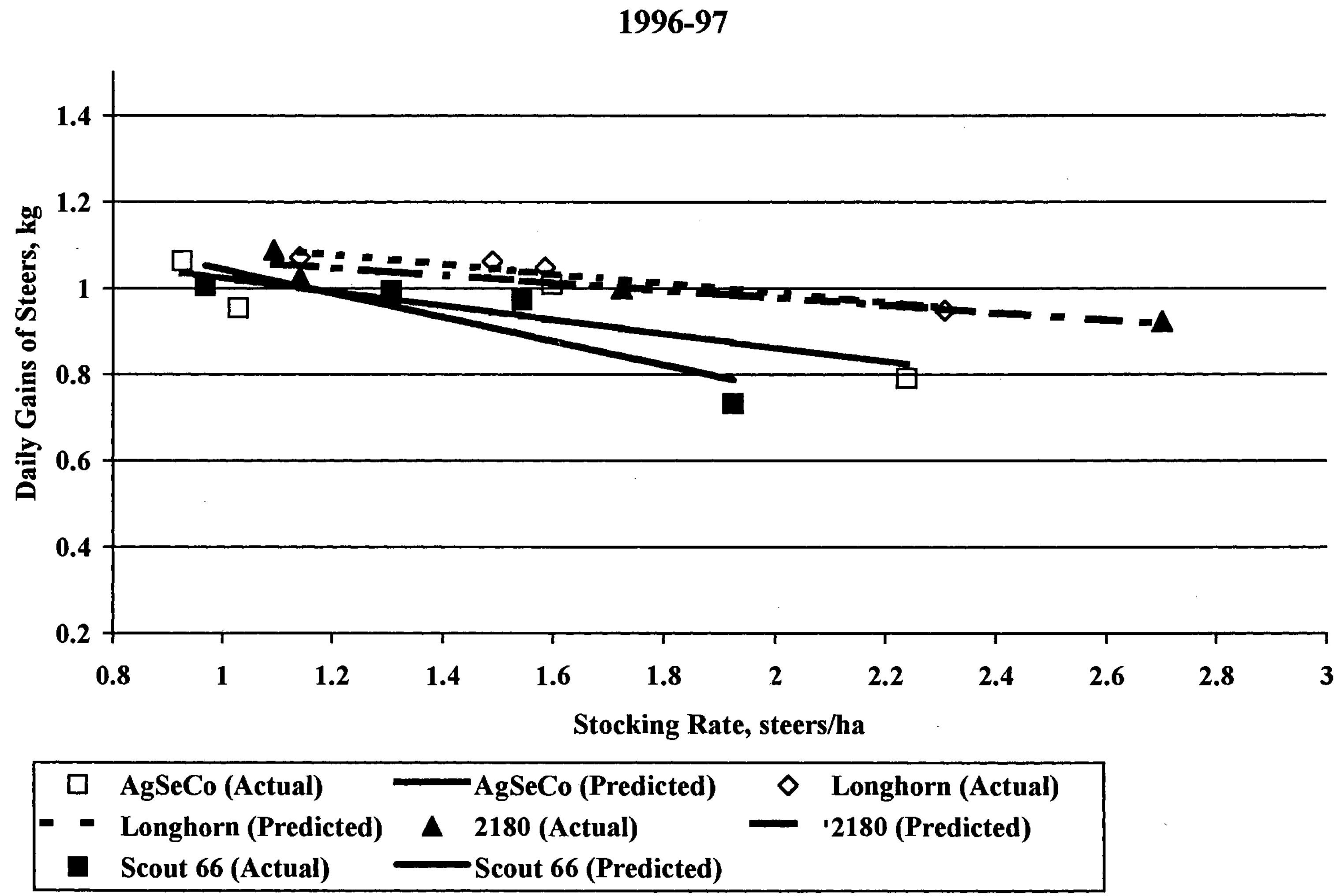

Figure 13. Daily gain of steers for variety x stocking rate study, year 4.

2

VITA

Steven Ira Paisley

Candidate for the Degree of

Doctor of Philosophy

Thesis: EVALUATION OF WHEAT VARIETY, STOCKING DENSITY AND SELF-LIMITED ENERGY SUPPLEMENTS ON PERFORMANCE OF STEERS GRAZING WINTER WHEAT

Major Field: Animal Nutrition

Biographical:

Personal Data: Born in Oshkosh, Nebraska on July 12, 1970, the son of Dick and Nancy Paisley. Married to Carrie Coleman in Wheatland Wyoming on December 30, 1994

Education: Graduated from Garden County High School, Oshkosh, Nebraska in May 1989; received Bachelor of Science and Master of Science degrees in Animal Science from the University of Wyoming, Laramie, Wyoming in December 1993 and May 1995, respectively. Completed the requirements for the Doctor of Philosophy degree with a major in Animal Nutrition at Oklahoma State University in July, 1998.

Experience: Raised on a family farm and ranch operation near Oshkosh, Nebraska; employed as a farm laborer during summers; employed by the University of Wyoming Beef Unit as an undergraduate and graduate student. Employed as a graduate research assistant; Oklahoma State University, Department of Animal Science, January 1995 to present.

Professional Memberships: American Society of Animal Science, Gamma Sigma Delta, Alpha Zeta.